Vol. 34 No. 2

BULLETIN

OF THE

TORREY BOTANICAL CLUB

FEBRUARY, 1906

Studies in etiolation

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(WITH PLATES 4 AND 5)

During the winter of 1902–1903 the writer carried on certain studies of the effects of etiolation upon several species of plants in the laboratories of the New York Botanical Garden. Most of the species studied were latex-bearing sorts. Owing to the press of regular duties, and to ill health, the publication of the results has been long delayed — far too long, indeed. It seems, however, worth while to present them briefly at this time. An announcement of the results obtained with *Persea* was made before the Botanical Society of America at its Washington meeting, January 1, 1903.

Seedlings of the Alligator pear (*Persea gratissima*) were grown in a dark room and propagating houses of the Garden, toward the end of 1902. At the end of ten weeks the normal and etiolated plantlets had developed stems approximately equal in length (about 45 centimeters) which consisted of 17 and 19 internodes respectively (plate 4, figure 7). The variation in the length of the internodes of the normal plantlets was slightly greater than with the etiolated. No acceleration was shown in rate of growth by the etiolated plants, nor was the total amount of growth greater than in the normal. The stem-diameters were nearly the same in both cases. All the leaves of the etiolated stems were bract-like and rudimentary (plate 4, figures 3 and 4); these did not advance beyond a certain stage of 10 mm. in length, with blades 5 x 2 mm., when they withered and dropped off. These rudiments seem generally comparable with the rudimentary organs borne on the basal

[The BULLETIN for January 1906 (33: 1–66, *pl. 1–3*) was issued 8 F 1906.]

portions of the normal stems. At the end of the period of growth studied, four weeks later, the thick cotyledons of the normal specimens were very much shrunken, discolored and decaying, while those of the etiolated plants were bright, plump, and yet retained reserve material. The contrast in this depletion of stored food was quite clear. An examination of the roots was made at the end of fourteen weeks and the total length of the roots of the etiolated plants was found to be about half that of the normal. The crowded and entangled growth of the roots of the normal plant was in marked contrast to that of the etiolated. A number of buds on the basal portion of the etiolated stems, including those axillary to the cotyledons, started into activity, but those of the normal stem remained dormant.

The cross-section of the middle portion of the normal stem (plate 4, figure 1) showed a fairly well developed woody cylinder about 300 μ thick, with definite cambium and numerous vessels in the wood. The bast-bundles were 48 in number, composed of lignified cells with laminae 3.5–4 μ thick, interspersed at times with unlignified, thin-walled cells; occasionally these latter contained chloroplasts. Usually the secondary bast-bundles were fairly well developed. The remaining cortex consisted throughout of thin-walled cells with a layer of more highly colored cells just without the bast, the whole covered by the unmodified epidermal cells. The cells of the pith frequently contained starch and the perimedullary ring was gorged with starch, as were also the medullary rays. The region of highly colored chloroplasts constituted also a well-marked starch ring at the base of the normal stem.

The cross-section of the etiolated stem (plate 4, figure 2) showed a woody cylinder 150–250 μ thick, consisting of slightly lignified cells, with less conspicuous cambium and with fewer and slightly smaller vessels in the wood. The bast consisted of the same number of bundles but with very slight development of the secondary bundles; the walls were thinner than in the normal and less lignified. The cortex contained fewer chloroplasts than the normal, while the two outer layers of the epidermal system were more or less collapsed and were underlaid by a well-marked hypodermal phellogen. The pith-cells of the etiolated stem were

larger than in the normal, while the same gorging of the stems with starch grains was noted in the perimedullary region and in the medullary rays. The earlier formation of phellogen in the etiolated stem may be interpreted as an adaptation to prevent drying out; this phellogen was present near the summit of the etiolated stem. This precocious phellogen formation, in this case with the early collapse of the epidermis, is similar to that observed by MacDougal in *Acer* and *Cornus*.*

Etiolated specimens with stems 50 to 60 cm. in length were brought into diffuse illumination near a window and in two months made an additional elongation of about 5 cm. The terminal newly formed portions of such stems bore about 7 normal leaves, with 8 or 10 internodes immediately below still retaining the bract-like organs resulting from etiolation (plate 4, figure 5). The lower portion of the stem, in which precocious development of phellogen had taken place, retained its brown color but was not extended, while the entire upper portion of the stem had become green. Young stems which had made but little growth in darkness made much more rapid growth than that described above for the older stems, and developed an equal crown of normal leaves.

The leaves of the normal plant (plate 4, figure 6) showed a single layer of palisade-cells and no stomata on the upper surface, as before noted by Solereder.† The petioles showed definite cambium, but the vessels gave no lignin reaction. The bract-like hairy leaves of the etiolated plant (plate 4, figures 3 and 4) showed no cambium in petioles, no stomata and no further differentiation of the tissues than an indistinct row of palisade cells, whose length and width were nearly equal.

Rootstocks of *Euphorbia corollata* obtained from Ohio, were also grown in light and darkness under conditions similar to those for *Persea*. No essential difference in the rate of growth, or in the total amount of tissue produced, was observed as between the normal and the etiolated growths of *Euphorbia* (figures *A* and *B*). There was noticeable variation in the thickening of the etiolated stems due to an increase of cortex by activity of the cambium layer.

* MACDOUGAL, D. T. The influence of light and darkness upon growth and development (Mem. N. Y. Bot. Gard. 2:) 97–100, 188–190. 1903.

† SOLEREDER, H. Systematische Pflanzenanatomie 774. 1900.

The determination of the water and dry matter in the stems of these specimens gave the following results:

DRY SUBSTANCE IN STEMS OF *Euphorbia corollata*

	Normal plant per cent.	Etiolated plant per cent. I	II	Average.
Water.....	86.90	91.11	89.63	90.37
Dry substance.....	13.10	8.89	10.37	9.63

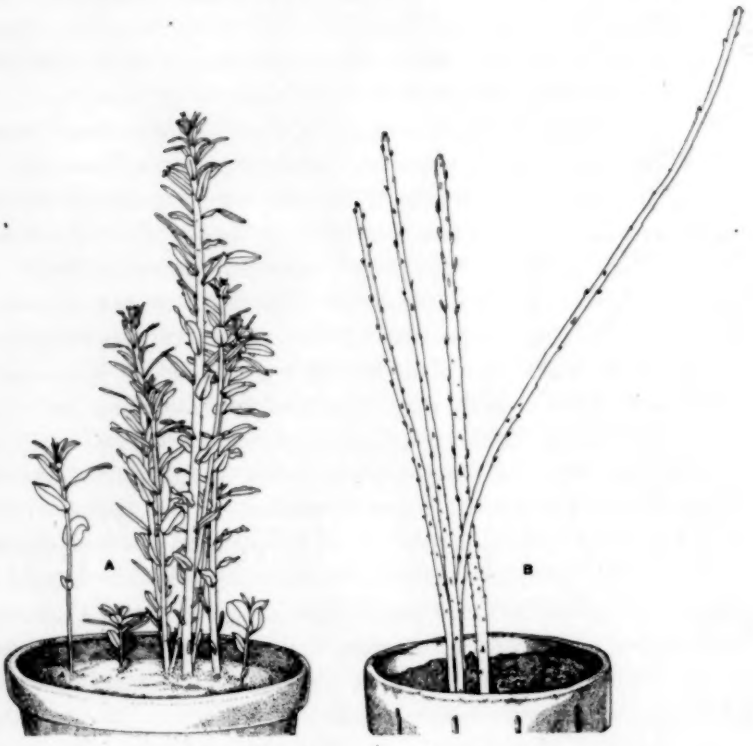

FIGURE A. Normal plant of *Euphorbia corollata*.
FIGURE B. Etiolated plant of *Euphorbia corollata*.

A transverse section of the stems showed (plate 5, figure 1) in the normal a rather feeble development of the strengthening tissue and a cambium of several layers of short cells. The woody parts of the cylinder were irregularly and feebly developed, bringing the groups of vessels into great prominence. The etiolated stem, as before stated, showed (plate 5, figure 2) a tendency to develop cortical parenchyma and the woody portion scarcely less devel-

oped than in the normal. These differences will be evident in the illustrations (plate 5, figures 1 and 2). Referring to the analysis it is observed that the increase in the thickness of the etiolated stems has not been accompanied by any considerable increase of solid matter and that the etiolated plant contains about 3½ per cent. more water than the normal. These results are in harmony with those previously obtained by others.

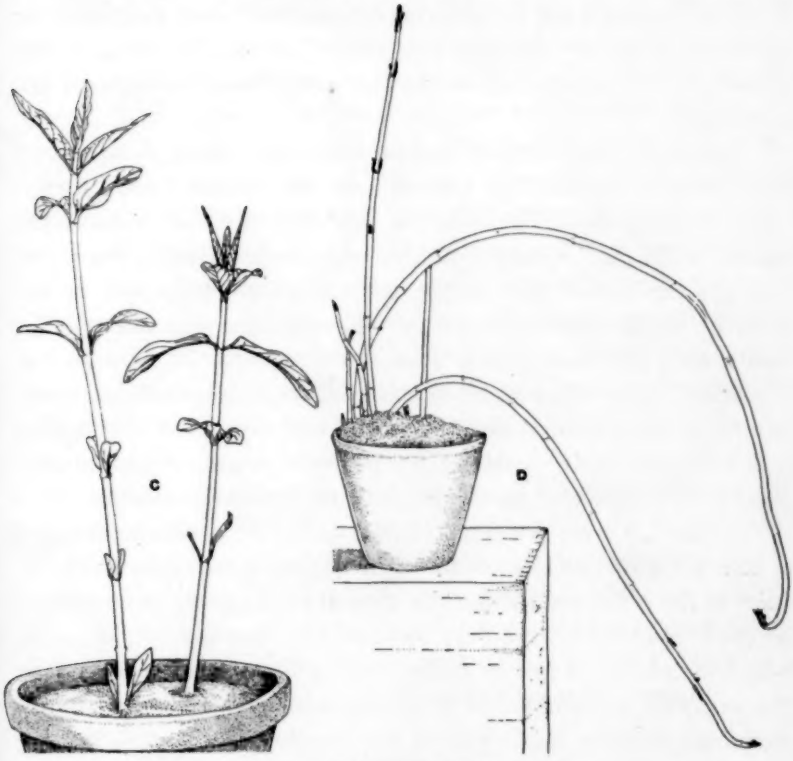

FIGURE C. Normal plant of *Asclepias incarnata.*
FIGURE D. Etiolated plant of *Asclepias incarnata.*

Roots of *Asclepias incarnata* were likewise collected at Wooster, and plants grown from them in the etiolating chamber and the propagating house of the New York Botanical Garden. The etiolated plants of this milkweed started to grow earlier than the normal, and produced longer stems (figures *C* and *D*). These developed as many as 13 or 14 internodes, with a length varying between 5 and 12 cm. The lower axillary buds of the etiolated

plants showed a tendency to start into activity during the growth of the main stem. The leaves were dropped from the etiolated stems, so that when the examination was made none were found below the tenth or twelfth internodes from the base; although in a few instances bract-like organs formed on lower internodes were retained for a long time. Normal stems of the same age produced but 7 to 9 internodes with an average length of 3–4 cm. It would appear from these facts that the abnormal length of the etiolated stems of this plant is due both to the exaggerated growth of the internodes and to the actual multiplication of the internodes.

The anatomical features present some interesting comparisons which may be studied by reference to the figures. In the etiolated stems (plate 5, figure 6) the cambium included four or five layers, while the woody cylinder and the bast-cells were less strongly developed than in the normal, as might have been expected. In the middle of the normal stem it was noted that the bast-sheath was more nearly continuous than at the base; a like condition, though less strongly marked, was also observed in the middle of the etiolated stem. In one instance an etiolated stem had become nearly prostrate by its own weight, and the apical portion had responded by an apogeotropic curvature which brought the tip into an erect position. Little difference could be detected in the structure of the central cylinder of these stems with respect to the convex sides, but the bast-fibers, scarcely differentiated on the convex side, were developed as well-marked strands composed of colums of two or three dozen cells in cross-section upon the opposite or concave side. This seems to show that while stretching tension might induce the development and differentiation of this tissue, the absence of stress, or positive compression resulted in the non-differentiation. Similar effects have been noted in special investigations, by various workers, dealing with the effect of compression and tension upon the mechanical tissues. Determinations of water were made in the normal and etiolated stems of this plant with the following results:

DRY SUBSTANCE IN PLANTS OF *Asclepias incarnata*

	Normal plant per cent.	Etiolated plant per cent. I	II	Average.
Water.....	86.58	91.83	91.57	91.70
Dry substance.....	13.42	8.17	8.43	8.30

Here we have wider divergence amounting to more than 5 per cent. difference in the dry substance of the normal above that of the etiolated stems.

Rootstocks of *Euphorbia Cyparissias* were brought from Wooster, Ohio, to the New York Botanical Garden, and after these had shown signs of activity were placed in suitable pots and some exposed to light while others were placed in the etiolating chamber, on March 20, 1903. The new stems were one to two cm. in height although none had formed chlorophyl to any noticeable extent. One month later the stem-lengths of the normal and etiolated plants were respectively 8 to 10 cm. for the normal and 6 to 8 cm. for the etiolated. It is evident that this plant does not support the assumption that light exercises an actual retarding effect upon growth.

Roots of *Apocynum cannabinum* were lifted and potted in November, 1902, and at this time duplicate pots were placed in the dark chamber and in the propagating house of the Garden; a large number of duplicates were cared for in the propagating house. The plants showed little tendency to make early growth in either situation. Toward the end of April, 1903, shoots began to appear on the plants in the dark chamber and a corresponding plant was set aside in the propagating house. In June, 1903, measurements were kindly taken by Dr. W. A. Cannon, laboratory assistant at the New York Botanical Garden. The etiolated plants attained a height of about 30 cm., while the normal specimens made no marked growth after having been set aside in April.

Similar results to those of *Apocynum* were obtained with roots of *Asclepias syriaca.* In this case the etiolated specimen attained a height of 30 cm. while the normal plant attained a length of but 5 to 6 cm., development being arrested for some reason.

Interpretation of results

It is evident from the foregoing that the phenomena of etiolation are not in themselves to be regarded as of a useful adaptive character, as put forward by many writers on the subject. In some instances it is conceivable that the undue elongation of stems that ensues might serve the useful purpose of carrying the apical part of the stem with its leaves past an obstruction intercepting the light, but a census of the species which have been sub-

jected to etiolation by MacDougal and others shows that less than half exhibit such elongations.

An important correlation-reaction is shown by the basal buds of etiolated stems. Numbers of such buds usually dormant are awaked in darkness and develop stems.

None of the facts derived from the study of the behavior of etiolated plants may be construed to indicate that light exercises a retarding effect on growth, however. If such a conclusion is to be maintained it must be justified on other grounds beside the results of studies of the action of plants in darkness.

A consideration of the structure of the plants studied in the work described above leads to the conclusion that when grown in darkness the tissues do not attain full development and that the differentiations by which the separate tissues are distinguished appear to be carried out only partially or not at all. The degree of incompleteness depends to some extent upon the organographic relations of the structures taken into consideration. This failure in the perfection of the tissues, which may even include their non-appearance, is very naturally coupled with a prolonged growth of the meristematic cells which by repeated division may thus increase either the thickness or the length of a stem.

Directly and indirectly, light seems to exert a stimulative effect upon the morphogenic processes leading to the differentiation of the tissues. If an etiolated shoot is brought into illumination, the portions in which the embryonic tissue has not gone beyond a certain age carry on development approximating the normal. Older etiolated tissues may form chlorophyl or undergo additional thickening of the walls, but no other differentiations in form are possible.

The formation of prosenchymatous cells in the concave side of a geotropically curving stem of *Asclepias*, in which they were lacking from the opposite convex side, is an excellent example of pure mechanical induction. In normal stems the development must set up, through the tension of the various tissues of the stem, stimuli which would induce the formation of prosenchyma regardless of the action of light. Now in the etiolated stem the bast-strands seem to be induced only by the bending strains exerted on the stems by their tendency to fall over, and the stresses

throughout the stem are otherwise equal, being simply those arising from turgidity. When such a stem is laid in a prostrate position and the embryonic cells of the apical portions of the stem produce a curvature in making an adjusting response, the stretching tension set up in the concave side of the stem acts as a stimulus inducing the formation of the mechanical tissue as described.

The writer wishes to express his great obligations to Dr. D. T. MacDougal, Director of the Laboratories of the Garden, for material aid and constant encouragement in the course of this work, and to make further acknowledgment of special assistance in the interpretation of results. The illustrations are chiefly from drawings made by A. Mariolle, of the Garden, to whom his best thanks are due.

OHIO AGRICULTURAL EXPERIMENT STATION.

Explanation of plates 4 and 5

PLATE 4

Persea gratissima

FIG. 1. Portion of cross-section of middle of stem of normal plant.

FIG. 2. Portion of cross-section of middle of stem of etiolated plant.

FIGS. 3, 4. Bract-like hairy leaves of etiolated plant, × 4½.

FIG. 5. Etiolated 10-weeks' seedling (same as figure 7), after two months' illumination, about one-fifth natural size.

FIG. 6. Leaf of normal plant, about one-half natural size.

FIG. 7. Etiolated 10-weeks' seedling, about one-fifth natural size.

PLATE 5

Euphorbia corollata

FIG. 1. Portion of cross-section of stem of normal plant.

FIG. 2. Portion of cross-section of stem of etiolated plant.

FIG. 3. Leaf of normal plant, two thirds natural size.

FIGS. 4, 5. Leaves of etiolated plant, × 1⅓.

Asclepias incarnata

FIG. 6. Portion of cross-section of middle of stem of etiolated plant.

FIG. 7. Portion of cross-section of middle of stem of normal plant.

FIG. 8. Portion of cross-section of concave side of curved stem of etiolated plant.

FIG. 9. Portion of cross-section of convex side of curved stem of etiolated plant.

FIG. 10. Leaf of etiolated plant, × 1⅓.

Studies on color in plants*

HENRY KRAEMER

The subject of color may be viewed in a number of ways. The physicist considers colored substances in their relation to light, and defines color as due to the influence which the substance has upon the vibration of the ether-waves and as dependent upon physical conditions. The chemist is interested in the constitution and composition of the colored substance, while the biologist is concerned with its origin and the role which it plays in metabolism or the life-processes of the plant or animal. The nature of *color in plants and animals* is more or less distinct, and while a number of animal pigments have been isolated, as cochineal and lac-dye, the color effects in animals are due largely, especially in the plumage of birds, to physical structure, *i. e.*, light interference phenomena or the dispersion of light rays. While structural arrangement in plants has also an influence on the color effects, still the colors in plants are usually looked upon as being due to distinct chemical principles without special reference to physical structure.

Upon making a section of some colored tissue of the plant, we find cells containing two or more of the following substances. In the first place there is in the living cell a semi-fluid, viscous, granular or foam-like substance known as *protoplasm*, of which, as regards its chemical composition and function, we know little more than when it was first described by von Mohl in 1846. This lies either close to the walls of the cell, forming a relatively thin layer or lining, which encloses a large vacuole of cell-sap, or it may be distributed in a mesh-work, forming smaller vacuoles. Within the protoplasmic mass we find a differentiated body known as the *nucleus*, and in recent years much of the work done by biologists has been devoted to a study of this body. There are in addition other protoplasmic bodies found in the plant cell, known as *plastids*,

* Read before the Torrey Botanical Club, with illustrations and demonstrations, December 12, 1905. More complete details of the work will be given in future issues of this BULLETIN.

which are much smaller than the nucleus and are distributed through the protoplasm in relatively large numbers. Of these there are two distinct groups, one containing a green pigment, which gives the green color to leaves, known as the *chloroplastid*, and the other containing a yellow pigment, which gives the yellow color to yellow flowers and fruits, known as a *chromoplastid*. In the vacuoles already referred to occur various coloring principles which are dissolved in the cell-sap and which give the various colors other than yellow to flowers and fruits, as blue in the violet or plum, red in the carnation, rose or apple, etc.

PLASTIDS AND PLASTID COLOR-SUBSTANCES

Regarding the structure of the plastids we know but very little. In all cases they consist of a protoplasm-like substance in which is held either mechanically or in chemical combination the green or yellow coloring principle. The *chloroplastids* in addition contain starch-grains, which are considered to be manufactured by the chloroplastid under the influence of sunlight from water and the carbon dioxide of the air; they may also contain proteid substances and oil. While the protoplasm has been termed by Huxley "the physical basis of life," this little chloroplastid, but the one five-thousandth of an inch in diameter, has been spoken of as the mill which supplies the world with its food, for it is by the process of photosynthesis that the energy of the sun is converted into vital energy, and starch and other products formed, which become not only the source of food for the plant itself, but also the source of the food-supply of the animals which feed upon plants. In other words, horse-power is derived from the energy of the sun which is stored by the chloroplastids in the plant.

In the *chromoplastid*, on the other hand, there are usually present, as first pointed out by Schimper and Meyer, protein substances in the form of crystal-like bodies; starch-grains may also be present. The chromoplastids are very variable in shape and in other ways are markedly different from the chloroplastids. They are more unstable than the chloroplastids, are formed in underground parts of the plant, as in the root of carrot, as well as in parts exposed to the light, as in the flower. Their formation frequently follows that of the chloroplastids, as in the ripening of certain yellow fruits, such as apples, oranges, persimmons, etc.

The *plastid pigments* are distinguished from all other color-substances in the plant by the fact that they are insoluble in water and soluble in ether, chloroform and similar solvents. This seems to be a wise provision, as it probably prevents the diffusion of these principles in the more or less aqueous cell-sap. These plastid pigments are but little affected by the usual chemical reagents under ordinary conditions.

Apart from the difference in color, the yellow pigment is distinguished from the green by the fact that the latter is said to contain nitrogen, and also by their difference in behavior when examined spectroscopically, chlorophyl giving several distinct bands in the yellow and orange portion of the spectrum, which are wanting in the spectrum of the yellow principle.

The leaf-buds of the skunk cabbage are quite large, consisting of numerous leaves. The innermost leaves are of a distinct yellow color. A microscopical examination of these shows that the color is due to a plastid which is very much smaller than the chloroplastids or chromoplastids found in the fully developed leaves and flowers of the plant. This plastid occurs in the palisade cells and contains neither starch nor proteid substances, and the yellow pigment appears to be somewhat similar to that found in chromoplastids, but differs in this, that on reducing with zinc it becomes slightly greenish. This plastid, which I have provisionally termed an *etioplastid* (and the pigment *etiophyl*), appears later, with the development of the leaf, to be transformed into a chloroplastid, whereas just the reverse takes place with chromoplastids, that is, they may be derived from chloroplastids. I may further say with regard to the pigment etiophyl, that on purification and treatment with zinc it appears to be entirely distinct from chlorophyl when viewed both by transmitted and reflected light and when examined by means of the spectroscope. It is also characterized by its greater stability even when exposed to light, and may be partly separated from chlorophyl in an alcoholic solution (85 per cent. alcohol) by means of benzin. An interesting observation which I have made in this connection is that when leaves of skunk cabbage containing both etiophyl and chlorophyl are extracted with alcohol, purified, and reduced with zinc, the resulting solution is a deep green and retains this color.

CELL-SAP COLORS

All the other color-substances found in plants besides the green and yellow principles just mentioned occur in the cell-sap, and may be in the nature of secondary substances derived from the plastid pigments, or they may be produced directly by the activities of the protoplasm. During the course of my work I have been much impressed by the fact that in tissues containing cell-sap color-substances, or as they might be termed *unorganized color-substances*, not infrequently strikingly contrasting colors are observed in contiguous cells; as in the petals of the poppy and petals of certain lilies, where we find some cells of a deep-purple, others of a deep-red and still others of intermediate shades. The same may be said of the germinating kernels of black Mexican corn. This observation has led me to believe that the shades of color in the pigmented cells are largely dependent upon the nature of the substances associated with the fundamental color-substance. The unorganized color-principles are easily extracted with water or dilute alcohol. I have examined the principles from several hundred plants, and find that they are all more or less affected by certain chemicals (many of which occur naturally in the plant), such as citric acid, oxalic acid, salts of calcium, iron, aluminum, etc.

A solution of the mallow flowers of the garden is of a purplish-red color and becomes green with lime water; deep-red with oxalic acid; purplish-red with alum; and deep brownish-red with ferric chloride.

A solution of rose petals (J. S. Fay) is of a more or less light-brown or pale yellowish-red color and becomes pure green with lime water; deep yellowish-red with oxalic acid or citric acid; purple with alum; and deep-blue with ferrous sulphate.

These reactions show that these color-substances are quite sensitive to the influence of chemicals, and many of them correspond to the class of substances known as indicators; in fact a number of plant pigments are used as indicators in volumetric chemical analysis, their use in this connection being dependent upon their sensitiveness to acids and alkalies. The fact that they respond to iron salts, that is, give a blue or green reaction with these salts, would indicate that they are associated with tannin or that they are tannin-like compounds, as has been supposed by

some writers. It may therefore be of interest to compare the reactions of tannin with those already given.

A solution of tannin, which is colorless, produces no color with lime water, with acids, or with alum; becomes deep-blue with ferrous sulphate, which is rather characteristic, and reddish-brown with alkalies. It is thus seen that tannin behaves very differently toward these reagents except in the case of iron salts.

An examination of the color-substances of a large number of plants shows that the flower color-substances are distributed in all parts of the plant. For example, the flower color-substance of the rose occurs in the leaves and prickles as well as in the petals, and this substance can be readily separated from the chlorophyl associated with it in the leaves by treating an alcoholic extract of the leaves with benzin.

In an alcoholic extract which has been so treated, the benzin layer at the top contains the separated chlorophyl and the alcoholic layer at the bottom contains the flower color-substance, which becomes more distinct by the addition of reagents.

The color-substance in the root of the radish closely corresponds to that in the flowers, and the color-substance in the grains of black Mexican corn corresponds to that in corn silk.

An extract of black Mexican corn shows reactions with chemicals closely resembling those obtained with various flower color-substances, as of rose.

The solution of black Mexican corn, which is of a reddish-purple color, rapidly changing to purplish-red, becomes green with lime water; red with oxalic acid; purple with alum, which is quite pronounced; and distinct blue with ferrous sulphate.

The cell-sap color-substances are usually found in greatest amount at the tips of the branches, this being well marked in the foliage of the rose, and may be said to be rather characteristic of spring foliage. Not infrequently in the purple beech the young leaves will be of a distinct purplish-red color and almost entirely free from chlorophyl, suggesting a correspondence in position and color to a flower.

The results of my work further seem to show that there is a fundamental cell-sap color-substance which occurs in two modifications in the plant, one becoming yellowish-red and the other pur-

plish-red with acids. These two modifications may occur in the same part of the plant, as in the petals of the poppy, or in widely separated parts, as in radish, where the substance which becomes yellowish-red with acids occurs in the root, and the one which becomes purplish-red occurs in the flower.

Inasmuch as these two modifications behave in addition differently toward other reagents, they might be said to show an analogy to some of the sugars, as well as other substances, of which two modifications occur.

The existence of two modifications of the fundamental cell-sap color-substance is well exemplified in the case of roses, some fifty sorts having been examined. The color-substances extracted from deep-red or crimson roses give a yellowish-red color with mineral acids, a deep-blue or purple with potash-alum, ferric chloride or ammonio-ferric alum. The solutions obtained from pale-red or pink roses give a purplish-red with mineral acids, a pale-purple or pale purplish-brown with potash alum, and olive-green with ferric chloride or ammonio-ferric alum. With some of the hybrid tea roses and some of the yellow roses intermediate tints are obtained by the use of these reagents corresponding to the colors in the parent plants.

COLOR IN AUTUMN LEAVES

The coloring matters in both spring and autumn leaves closely resemble the cell-sap color-substances of flowers, although it is the spring leaves which give the most satisfactory results. The fact that in the autumn leaves there is little or none of the plastid pigment present would point to the conclusion that the color-substances occurring in these leaves are in the nature of by-products and of no further use to the plant. Of course in the case of autumn leaves we know that these products cannot be further utilized, and for this reason we are justified in regarding them as waste products.

COLOR IN MARINE ALGAE

The marine algae offer interesting material for the study of vegetable color-substances, and probably will be found to throw some light on the subject of the origin of color in plants. The plastids are numerous, constituting a large proportion of the components of the cell. They are variously colored, being red in the red algae,

brown in the brown algae, etc. The color-substances are more or less difficult to extract. The *chlorophyl* can be extracted by the use of absolute or 95 per cent. alcohol, except in the case of some of the more delicate red forms like *Griffithsia*, *Dasya*, *Grinnellia*, *Callithamnion*, *Agardhiella*, etc., where it is necessary to place the material direct from sea-water into a saturated solution of sodium chloride and afterwards treat with alcohol.

While the *red and brown color-substances* are for the most part difficult to extract, still some of them can be extracted quite easily with water or dilute alcohol, and these show an analogy in their behavior toward reagents to the cell-sap color-substances of the higher plants.

It would appear from a microscopical study of the marine algae that all the color-substances arise in the plastids. The difficulty in extracting these substances in most cases leads to the supposition that either owing to the composition of the plastid or of the cell-sap, the color-substances are held by the plastids and not diffused in the cell-sap as in the higher plants, *i. e.*, the cell-sap color is held in the vacuolules of the plastids.

PRESERVATION OF PLANT SPECIMENS

The fact that the red and brown coloring substances of these marine algae were held back or rendered insoluble by the use of a saturated solution of common salt, suggests the use of this solution as a preservative of not only marine algae, but also of fruits, flowers and vegetables for study or exhibition purposes. Specimens have been preserved in this manner, some of them for more than a year. I may add, however, that not all specimens can be preserved with salt solution.

EXPERIMENTS IN CONTROL OF COLOR IN PLANTS

That the color in plants is influenced by a number of factors, including light, temperature and soil, is well known. One of the most common examples showing the influence of light is furnished by certain sorts of apples, those portions of the fruits exposed to the direct sunlight being most highly colored. The influence of temperature on the color of plants is also illustrated by the highly colored red apples of higher latitudes. It is a matter of general

observation that the intensity of color is in direct ratio to the amount of sunlight and coolness of temperature, that is, of course, within certain limits. On the other hand, high temperature and diminution of light tend to decrease the intensity of color. The combined effect of sunlight and coolness of temperature is also seen in the foliage of the plants of alpine regions and higher latitudes, as well as in the spring and autumnal foliage of plants in the temperate regions.

The supposition that certain constituents of the soil perceptibly modify the color of plants probably dates from the experiments of Risse, who found that the so-called "zinc-violet," a blue-flowered form of *Viola lutea* (one of the alpine violets of Europe), grows in a soil containing 20 per cent. of zinc oxide, and that the ash of the plant contains as much as 1 per cent. of zinc oxide. The fact that this "zinc-violet" maintains the blue color when transferred to a soil which does not contain zinc, together with the fact that the color varies when grown in a soil containing zinc, led Hoffmann to conclude that the presence of zinc had no influence on the color. On the other hand, it is commonly supposed that the blue color of hydrangea is due to the addition to, or presence in, the soil of certain chemicals, as alum or iron filings. It is also a common practice among rose growers to treat the soil with a solution of copperas or ferrous sulphate (approximately 1 part of salt to 1,000 parts of water) in order to intensify the color of red roses. But curiously, the same treatment appears to decrease the intensity of color in the pale-red roses.

The fact that plant color-substances are modified to a greater or less extent by certain chemicals, as already indicated, led to the idea that it might be possible to influence the color-substances in plants by feeding the plants with chemical substances. The creation of color-principles is quite another problem.

During the past year I have been experimenting with roses, carnations and pansies, using the following chemicals: Acetic acid, citric acid, malic acid, phosphoric and other acids; various iron salts, as the acetate, citrate, chloride, sulphate, etc.; certain aluminum salts, as sulphate, phosphate, and the double salts of aluminum and potassium sulphate and aluminum and ammonium sulphate; ammonia water, potassium hydrate, ammonium nitrate,

potassium nitrate, potassium iodide, iodine, potassium cyanide, etc. These chemicals were supplied to the plants through the soil, beginning with a strength of 1 part of chemical to 10,000 parts of water. The strength was gradually increased until that of 1 part of chemical to 1,000 parts of water was reached. It was found that most of these chemicals could be supplied in this strength every five days for some months without injury to the plants. In other words, each plant could be supplied with 75 milligrams of chemical every five days without injury. With the exception of solutions of iodine and potassium iodide, and of potassium cyanide, it was found that a plant in a six-inch pot could be supplied with as much as 300 milligrams of chemical, an equivalent of 150 c.c. of a solution containing 1 part per 500 every five days. It was also found that plants growing in garden soil could be treated with a stronger solution of chemical than those growing in either sand or artificial soil. Plants which would stand treatment with a solution of potassium cyanide, 1 part to 1,000 parts, when growing in garden soil, were killed by a solution of this strength when growing in sand or an artificial soil.

RESULTS OF COLOR-CONTROL EXPERIMENTS

So far as I have been able to see, the treatment with the color-control solutions has not produced any marked effects. Some slight changes have been noted, but these could perhaps be ascribed to other causes as well as to the solutions. For instance, it was noted that in yellow roses supplied with aluminum and potassium sulphate the leaves and stems were slightly reddish and the flowers a deeper yellow than others, while those supplied with potassium hydrate were paler than the type. In the case of the La France rose plants supplied with iron citrate and citric acid the petals were of a uniform pink color.

The inner petals of plants supplied with iron malate and malic acid were pale in color, while the inner petals of plants which were supplied with either formic acid, ammonium nitrate, or iron salicylate and salicylic acid were of a deep-pink color. In the case of maroon roses, the petals tended to a deep purplish-red when treated with potassium cyanide or potassium nitrite; to a dark-red when supplied with phosphoric acid, iron and ammonium

sulphate, or sulphuric acid. In fact the color of the maroon roses approached that of the crimson roses when treated with sulphuric acid, and they also tended to singleness.

The scarlet carnation, when supplied with any of the following chemicals, showed a tendency to form white streaks in the petals: iron and ammonium sulphate; aluminum phosphate; iron citrate and citric acid. The maroon carnation, when fed with ferrous sulphate, also showed this same tendency. The petals of a white carnation, when the plant was fed with potassium and aluminum sulphate, showed a tendency to form red streaks.

There was a disposition on the part of the plants treated with potassium cyanide to produce less chlorophyl. In the case of the roses and pansies the leaves were beautifully variegated; in one of the roses growing in sand the edges of the leaves were red, the veins green and the remaining portion yellow. An insufficient supply of iron is generally supposed to produce a paling of leaves, but our observations have not confirmed this. This would tend to show that in certain plants iron is not as necessary as is commonly supposed.

The chief difficulty in experiments of this kind is to achieve and maintain exact control conditions. My work may now be said to be approaching these conditions, and my previous experiments must be regarded as more or less preliminary. It is well known that, when plants grow in a soil containing excessive amounts of copper or zinc, the plants take up these elements, and this demonstrates that the plant will take up certain chemicals under certain conditions, whether they assimilate these or not or whether they are poisoned by them. Until we can establish control conditions whereby we can determine the effects of each substance supplied the plant on different parts of the individual plant, we shall not be able to say just what is the effect of a chemical under varying conditions.

In the interesting experiments of Hoffmann already referred to, on the zinc violet, while he is inclined to consider that individual variation may account for its variability in color, still he says that possibly a difference in climate or physical character of the soil may have influenced the results. While the plant has certain inherent qualities or tendencies which are more or less difficult to

influence, and which perhaps can not be modified except within certain limits without injuring the plant, still, by reason of the more or less unspecialized character of the protoplasm, the plant is more or less plastic and susceptible of modification in various ways, and who can say just what the limits are in any one direction? At least we should not allow ourselves to become dogmatic with regard to this problem. As already enumerated, the external factors influencing color in plants are light, temperature, and soil, including certain atmospheric conditions both physical and chemical. When as much work has been done along these lines as in selection and hybridization, we shall probably understand much better than we do now the causes influencing the variation in the colors of plants.

ARTIFICIAL COLORING OF FLOWERS

A few years ago a gentleman traveling in Italy saw a pink iris in one of the florist's establishments which interested him very much and which he desired to purchase. He then learned that the iris had been artifically colored, and that that particular plant was not for sale. He was, however, able to purchase some of the solution for coloring the flowers, but found to his disappointment on arriving home that the solution did not work.

Within the past year or two quite a demand has been created for green carnations on St. Patrick's day. During the course of my experiments it occurred to me that it might be possible to take a plant which was deficient in coloring matter and add to it the extracted coloring matter from some other plant. There is a record that as early as 1709, Magnol colored the flowers of tuberoses by placing the stems in the red juice of poke-berries. Even the botanist Unger (1850) stated that the white flowers of the hyacinth could be colored by adding poke-berry juice to the soil. I have been unable to confirm these observations by the use of any natural coloring substance. For nearly fifty years various artificial coloring substances have been used in the study of the ascent of cell-sap. While considerable attention has been given to the ascent of these substances in the stem, not much attention has been given to their effects on flowers, although here and there in the literature one will find a statement with regard to certain effects of this kind.

In addition to experimenting with vegetable coloring matters, I have experimented with quite a large number of aniline dyes, and have obtained some rather striking results. These dyes are readily soluble in water, and the solutions are made up of a strength of 1 part of dye to 1,000 parts of water. The effects are best seen in white flowers and are produced by allowing the flower-stalks to remain in the solutions from one to two hours, when they are placed in water. With some flowers, as the cultivated anemones, the effects are noticeable in from ten to fifteen minutes. The results show that some flowers will take up the dyes better than others, and also that only a comparatively few of the thousands of aniline dyes can be utilized for the coloring of flowers. These belong chiefly to the classes of azo and rosaniline coloring matters, the acid dyes or those used for dyeing wool producing the best effects. White flowers may be changed to yellow, orange, blue, green, purplish-red or magenta, crimson, purple, salmon-pink or gray by the use of the following dyes:

1. Yellow flowers are produced by the use of the dye known commerically as "Acid Yellow A. T.," which is chemically the sodium salt of disulpho-diphenylazin-dioxytartaric acid.

2. Orange-colored flowers may be produced by the use of the dye "Orange G. G.," which is the sodium salt of benzene-azo-B-napthol-disulphonic acid.

3. Blue flowers may be produced by the use of the dye "Cyanol F. F.," which is the sodium salt of meta-oxy-diethyl-diamido-phenyl-ditolyl-carbinol-disulphonic acid.

4. Green flowers may be produced by the use of equal parts of the dyes "Acid Yellow A. T." and "Cyanol F. F."

5. Purplish-red flowers are produced by the use of the dye "Acid Magenta," which is the sodium salt of the trisulphonic acid of rosaniline.

6. Crimson flowers may be produced by the use of equal parts of the dyes "Acid Yellow A. T." and "Acid Magenta."

7. Purple flowers may be produced by the use of equal parts of "Cyanol F. F." and "Acid Magenta."

8. Salmon-pink flowers may be produced by the use of the dye "Brilliant Croceine M. O. O.," which is the sodium salt of benzene-azo-benzene-azo-B-naphthol-disulphonic acid.

9. Gray flowers may be produced by the use of the dye "Naphthol Black B.," which is the sodium salt of disulpho-B-napthalene-azo-A-napthalene-azo-B-naphthol-disulphonic acid.

I have also tried feeding these solutions to the growing plants, and found that carnations growing in an artificial soil, the basis of which is sand, will take up the solutions and show the effects in the flowers. The dyes are taken up chiefly through the tissues of the veins and are gradually diffused in the adjoining cells. The plants are not injured by the solutions, and if they are properly used neither the texture nor odor of the flowers is affected.

While the artificial coloring of flowers in the manner described is of more or less interest from the scientific point of view, it has also a practical application. In decorative schemes where a particular color is selected this method could be used for producing flowers all of one color, such as blue roses, blue carnations along with violets and other blue flowers. Or in some instances, where the demand for flowers of a certain color is greater than the supply, artificially colored flowers could be produced from white ones.

These dyes may also be used to intensify flowers having a pale color at this season of the year, as pale-yellow carnations, pale-pink roses, pale-yellow snap-dragon, etc. In some cases the natural colors can be modified, as in the production of yellowish-red flowers of snap-dragon from yellow flowers. In the production of novelties, as in the production of green carnations and green roses, the method can be utilized. The color produced by Naphthol Black B. is a delicate gray or grayish-black, and it has been suggested that roses and carnations colored with this dye would furnish appropriate mourning flowers. Another use of these dyes is in the coloring of wild flowers for decorative purposes. For example, wild carrot when colored with a blue dye gives a beautiful effect, being suggestive of a head of forget-me-nots.

The colors of flowers so dyed are permanent, and the dried flowers can in some instances be used for ornamental purposes, as in the case of hydrangeas, which are frequently used in the dried condition. There may be a possible application of these results in the manufacture of artificially colored dried flowers and plants for decorative purposes.

SUMMARY

My observations on the subject of color in plants, may be summarized as follows:

1. There are two classes of color-substances in plants:

(*a*) Organized color-principles which are characterized by being an organic part of the plastid body, and insoluble in water or dilute alcohol, but soluble in xylol and similar solvents.

(*b*) Unorganized color-principles, which are not a fundamental or organic part of the plastids, and occur either in the vacuoles of the cells of higher plants as well as fungi, or in the vacuolules of the plastids of the brown and red sea-weeds. They are further distinguished by being soluble in water and dilute alcohol, and insoluble in xylol and similar solvents.

2. The plastid pigments, or organized color-substances, may be divided into three groups according to their origin.

(*a*) Chlorophyl, which occurs in the chloroplastids in both higher and lower plants, and is especially distinguished by the appearance of its solution when viewed by means of the spectroscope.

(*b*) Chromophyl, which occurs in the chromoplastids, plastid bodies which are peculiar to the higher plants. The chromoplastids together with the accompanying pigment are found in many flowers, in certain roots, and follow the development of the chloroplastids in the ripening of many fruits.

(*c*) Etiophyl, which is found in an etioplastid occurring in the palisade-cells of the innermost leaves of the leaf-bud of *Spathyema foetida*. It is distinguished from chromophyl by becoming slightly greenish when reduced with zinc. The etioplastid is distinguished from the chromoplastid by the fact that its development precedes that of the chloroplastid.

3. In the photosynthesis of the chloroplastid, unorganized color-substances may be produced in comparatively large amount, as in

(*a*) Early spring foliage;

(*b*) The foliage of alpine plants as well as autumnal foliage;

(*c*) The brown and red marine algae;

(*d*) The foliage of certain species or varieties of rose, beech, nasturtium; etc.

4. Unorganized or cell-sap color-substances are distributed

usually in largest amount at the termini of the branches, as in flowers and terminal leaves, or in roots, or in both tops and roots. Their occurrence in those portions of the plant which are young and growing, points to the conclusion that they are not to be disregarded in the study of metabolic processes. Goebel likewise holds to this view. He says that it is "very probable that the feature of color which so often appears when the propagative organs are being brought forth has some connection with definite metabolic processes, although up till now we cannot recognize what these are."

5. The distribution of the so-called flower color-substances in other parts of the plant than the flower also points to the same conclusion, and that the part which they play in attracting insects to flowers is incidental rather than fundamental. (The fact that certain colored flowers as in spruce are pollinated by the wind, would tend to confirm this view.)

6. The occurrence of chromoplastids in a reserve organ, as in the tuberous root of carrot, and the similar occurrence of chromoplastids and of reserve starch in the petals of the buttercup, lead to the inference that the petal of the buttercup, like the root of the carrot, has the function of storing nutrient material. In each case cells containing chromoplastids rich in nitrogenous substances are associated with cells containing reserve materials.

7. The feeding of plants with chemicals or color-control solutions has not so far, in my hands, produced any marked changes in the colors of the flowers, only some slight effects being noted which might be attributed to other causes. Knowing that plants have a certain individuality and certain inherent qualities or tendencies, one could hardly expect other than negative results. On the other hand we know that the plant is a rather plastic organism, and for this reason we are more or less justified in carrying on experiments along the line indicated.

The fact that of thousands of dyes or color-substances only a few are taken up by the plant and carried as high as the flower, would tend to the probability that only certain chemicals or substances would be taken up and thus exert an influence upon the coloring matter in the flower. If such profound changes arise in plants as are provided by the mutation theory, is it too much to

suppose that certain definite changes may be produced by means of which we have knowldege or control?

PHILADELPHIA COLLEGE
OF PHARMACY.

The influence of moisture upon the formation of roots by cuttings of ivy

HARRIET RANDOLPH

When pieces of the leafy stem of English ivy (*Hedera Helix* L.) are kept for a time with one end immersed in water or in damp sand, roots generally arise on the part that is submerged. If the stem is then transplanted into soil, the new roots continue to grow and the piece of stem becomes an independent plant. This is the familiar method of raising new individuals from slips.

These new roots may arise close to the cut end of the stem and in any one or in all of the submerged internodes above the cut. They are white and thickly covered with root-hairs. Their structure in cross-section is shown in figure 3. When transplanted, the structure of the part subsequently formed in the soil is very like that of the part that grew in water.

The holdfast-roots, *i. e.*, the outgrowths along the side of the stem by which the ivy clings to the wall, under ordinary circumstances remain unchanged in the water. If kept there for a long time, the outer tissues decay and fall away, leaving the thicker-walled central part.

Experiments to be described below have shown that under varied conditions the ivy may send out roots that differ in some respects from these two kinds.

If the slips in water are kept in a greenhouse or in a room where the air is somewhat more moist than the normal, it sometimes happens that growth is set up in the submerged holdfast-roots. Delicate white outgrowths covered with root-hairs make their appearance either (1) from the tip of the holdfast-root, or (2) from some point along its side, or (3) from the matted felt-like complex formed by the growing together of several holdfast-roots as they attached themselves to a wall. (Figure 1, *hra*, showing near the lower end of the stem absorptive roots arising from the side of the holdfast mat that had adhered to the stone.) These secondary outgrowths from the holdfast-roots may occur in any of the submerged internodes and without any apparent relation to

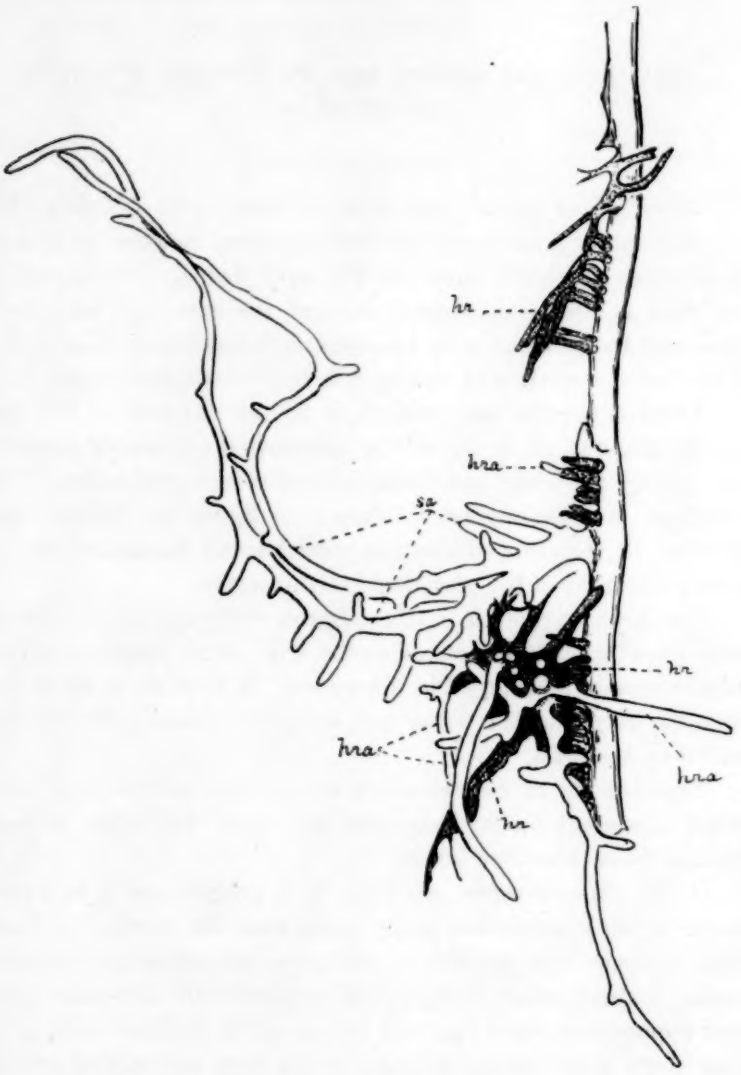

FIGURE 1. Traced from a photograph of ivy stem grown in a greenhouse in air slightly moist, showing the part of the stem that was under water. The lowest group of holdfast-roots (*hr*) had grown together, forming a felt-like mat whose distal surface, which had adhered to a wall, is turned toward the observer. From this distal side of the mat of holdfast-roots absorptive roots (*hra*) have arisen. A group of absorptive roots springing from the stem (*sa*) slightly above has been turned aside in order to leave the view of the holdfast-roots and their outgrowths unobstructed.

the presence or absence of absorptive roots from the stem. The secondary roots increase in length and are not distinguishable in appearance from the ordinary roots that arise from the stem.

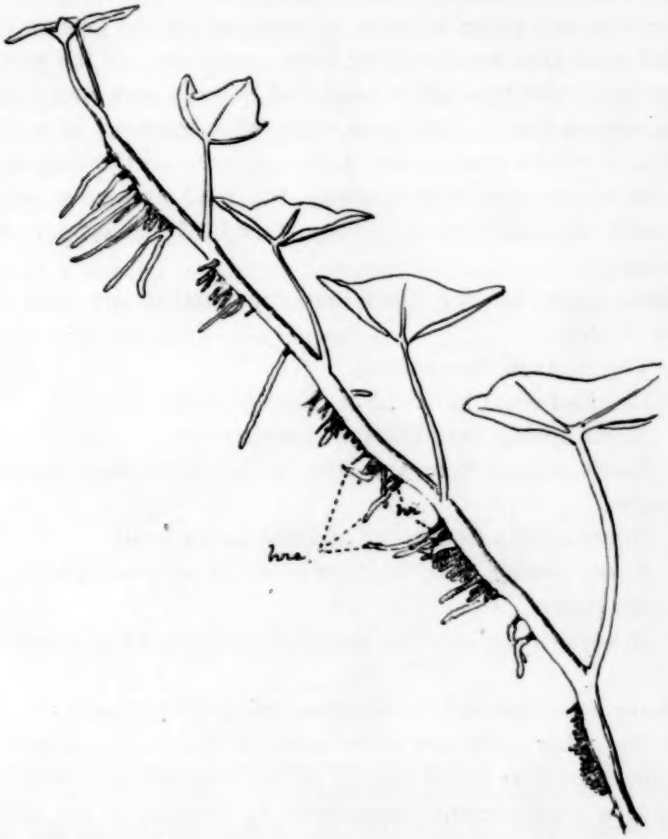

FIGURE 2. Traced from a photograph of young stems growing in water in air saturated with moisture, cut in May when the holdfast-roots had begun to appear. Many of the holdfast-roots (*hr*) have continued to grow, but the part grown in saturated air (*hra*) has a different structure from that of the original holdfast-roots. The holdfast-roots nearest the growing end of the stem had scarcely appeared when the stems were cut.

If the slips in water are kept in an atmosphere saturated with moisture, roots sometimes arise from the part of the stem that is in the air, above the surface of the water in which the stems are standing. They appear to arise indifferently on stems with leaves and on stems from which the leaves had been cut off at the begin-

ning of the experiment. These roots, like those above mentioned that grow from holdfast-roots, have the same appearance as roots that grow from stems under water.

If young stems with green holdfast-roots beginning to grow out are kept in a vessel of water in saturated air, the growth of the holdfast-roots that are above the water continues, but the part that has grown in saturated air is white and covered with root-hairs.

In one instance, occurring in some slips growing in a pot of damp sand in the greenhouse, roots appeared on the sides of the stems about two centimeters above the sand and grew out and downward obliquely into it. They resembled the prop roots of Indian corn.

Thus under varying conditions the English ivy has seven classes of roots:

1. The roots of the seedling.
2. Holdfast-roots by which it clings to walls.
3. Roots arising from the stem under water.
4. Roots arising from the stem in an atmosphere saturated with water.
5. Roots arising from holdfast-roots under water.
6. Roots arising from holdfast-roots in an atmosphere saturated with water.
7. Roots arising from the stem over moist sand in greenhouse air.

I have not examined the structure of roots of class 1.

In the other roots the same kinds of tissues are present, but there are differences in the size or in the number of certain cells that give a characteristic appearance to sections of the different roots.

The structure in general is as follows: The epidermis consists of two (in one case of three) layers, with (or without) root-hairs; the cortical parenchyma is about five cell-rows in thickness; the endodermis surrounds the fibro-vascular bundles; and in the center there is a column of sclerenchymatous cells. Lying within the endodermis, next to it and also next or very near to the outer vessel of each bundle, are ducts lined by secreting cells. When the roots increase in thickness the ducts continue to lie next to the endodermis.

In the common roots that grow out in water from the stem (class 3) the parenchyma has very thin walls, and thus the epidermis and the endodermis are sharply differentiated from it. In these roots, and in the roots that grow out from them after transplantation into earth, the secreting cells are about the size of the cells of the surrounding tissue. The secreting cells contain dense protoplasm and the ducts are empty. The sclerenchyma of the central column is shaped in transverse section like a sharp-pointed star (figure 3).

In the following kinds of roots the ducts have contents * and the central sclerenchyma cells are more numerous and in section resemble a regular pentagon. Hence the phloëm is farther removed from the center of the stem and the endodermal ring is larger than in common water roots, etc.

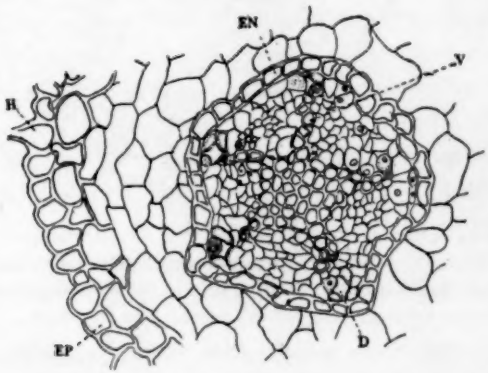

FIGURE 3. Cross-section of absorptive root springing from the submerged part of the stem of ivy in water. *d*, duct; *en*, endodermis; *ep*, epidermis; *h*, hair; *v*, vessels.

In the holdfasts (class 2) the epidermis is from two- to three-layered, and root-hairs are entirely absent or sparse (figure 4).

Adjoining or very near to each set of vessels of the holdfast-roots and on their peripheral side is a duct containing a yellowish substance and bounded in cross-section by four cells. This substance is probably the cement by which the holdfast-roots adhere to foreign surfaces.† Ducts are present in the cortical parenchyma of the stem, with contents apparently similar but with walls consisting of a greater number of cells (figure 5).

* The roots here described were all preserved in Flemming's solution.

† DARWIN, C. Climbing plants 187, 188.

In roots arising from holdfasts (class 5) the secreting cells are from two to three times the size of the largest cells of that region, and their ducts, like those of the holdfasts contain a yellow substance.

In the roots arising from the stem in air saturated with moisture (class 4) the epidermis is without root-hairs, the secreting cells of the ducts are about four times the size of the largest of the neighboring cells, and the ducts contain a brownish-black substance.

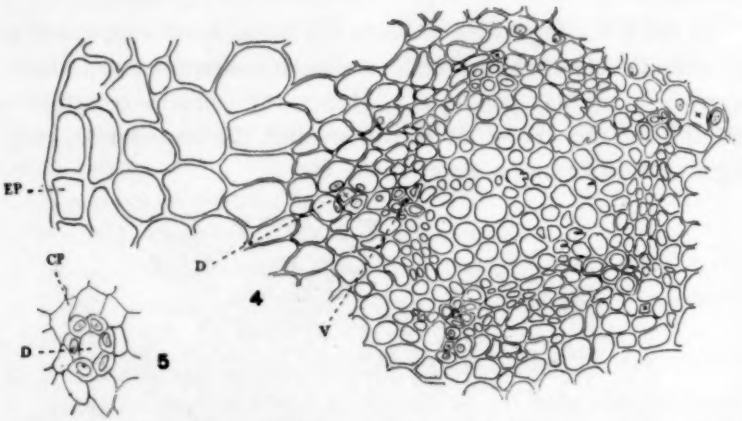

FIGURE 4. Cross-section of holdfast-root of ivy. *d*, the cavity of the duct (also marked ×); in some cases there are six sets of vessels; *ep*, epidermis; *v*, vessels.

FIGURE 5. From the stem of ivy, showing duct in the cortical parenchyma. It lies near the fibro-vascular bundles. *cp*, cortical parenchyma; *d*, duct.

In the corn-like roots which arise from the stem (class 7) the secreting cells are much larger than any of the surrounding cells, and the ducts (like those of the roots arising from the stem in air saturated with moisture) have brownish-black contents. Granules of this substance collected on the inner sides of the cell-walls bordering on the lumen were especially well seen in longitudinal section. These roots contain from six to nine vessels in a bundle, while in all the other kinds of roots the number varies from two to five.

The ivy, *Hedera Helix* L., is the typical example of dimorphism of shoot and leaf. * The possession of absorptive roots growing out into moist air from the holdfast-roots brings the ivy into rela-

* SCHENCK, H. Beiträge zur Biologie und Anatomie der Lianen 1: (SCHIMPER, A. F. W. Botanische Mittheilungen aus den Tropen 4:) 93, 94. 1892.

tion with the tropical vines which send down roots to the soil from different points along the climbing stem. These roots (Nährwurzel) convey to the upper parts of the vines a supply of water for which their thin stems are wholly inadequate.* Roots of this kind arising from the stem are believed to have their phylogenetic origin from holdfast-roots (Haftwurzel).† The roots that now grow out from the holdfast-roots of the ivy may represent an early stage of this process. The presence of large numbers of root-hairs is evidence that these secondary roots that spring from the stem have the function of absorption. As in the case of the tropical vines,‡ there is in the ivy a difference in structure between the absorptive roots and the holdfast-roots.

The presence of secondary absorptive roots in the ivy brings this species into closer relation with other members of its family (*Araliaceae*) in the tropics, and with epiphytes in general. Schenck§ states: "In fast allen Familien oder Gattungen mit wurzelkletternden Lianen begegnen uns gleichzeitig auch epiphytische Formen. So enthalten die Araliaceen in den Tropen epiphytische Holzgewächse. . . . Wurzelkletterer und Epiphyten sind verwandte Vegetationsformen, und aus ersteren können sich leicht letztere herausbilden, falls die Verbreitungsmittel der Früchte oder Samen entsprechende sind. . . . In der That giebt es ja auch viele kreichende oder wurzelkletternde Epiphyten, welche in manchen Eigenthümlichkeiten mit den echten Wurzelkletterern übereinstimmen."

BRYN MAWR COLLEGE.

* SCHENCK, *loc. cit.* 106.

† GOEBEL, K. Organographie der Pflanzen 488. 1900.

‡ GOEBEL, *loc. cit.* 487.

§ *Loc. cit.* 111.

The species of Lycopodium of the American tropics

LUCIEN MARCUS UNDERWOOD AND FRANCIS ERNEST LLOYD

In 1900 we published a preliminary list of the West Indian species of *Lycopodium* in connection with a revision of the species of temperate North America.* During the few years that have since elapsed, our knowledge of the tropical species has been greatly extended, chiefly through the explorations that have been made in various parts of the West Indies under the direction of the New York Botanical Garden. The expeditions to Porto Rico by Underwood and by Wilson, to St. Kitts by Britton and Cowell, to Cuba, by Britton, Shafer, and Wilson, and by Underwood and Earle, to Haiti by Nash, to Jamaica by Underwood and by Maxon of the United States National Museum, and to Dominica by Lloyd have all brought back an extensive array of material. This has been amply supplemented by the Jenman collection purchased by the Garden in 1903, which is specially rich in material from Jamaica, Grenada, Martinique, and Guiana. Other recent South American material has been supplied through the rich collections of H. H. Smith in the Santa Marta region of Colombia, and of R. S. Williams in the Andean region of Bolivia. The latter collection particularly has brought to light a number of very interesting species. American collections are still lacking in good representative material from Brazil, and there are occasional species from other regions about which additional light is still greatly desired. In order to place our present knowledge in an accessible form, we present this second preliminary report on the species of the West Indies and Mexico, and have included occasional species from South America. The West Indian forms are now fairly well limited and localized, yet it is not impossible or even unlikely that still other species will be found in the archipelago when the higher altitudes of the larger islands shall have been explored. The Mexican and especially the Central American species are much more obscure, and must await further exploration. The same is

* LLOYD, F. E. & UNDERWOOD, L. M. A review of the species of *Lycopodium* of North America. Bull. Torrey Club **27** : 147–168. 1900.

even more true of South America, which is likely to yield species yet unknown, as well as much more definite information about many that are now only imperfectly known.

All descriptions of structural characters are based upon material prepared by boiling, and upon glycerin-jelly microscopic preparations, of which in all instances camera-lucida drawings were made to a uniformly applied scale.

The three sections of the genus *Lycopodium* that are represented in the American tropics may be distinguished as follows:

Foliage leaves normally many-ranked, mostly uniform.
- Sporangia in the axils of unaltered leaves. § 1. *Selago.*
- Sporangia aggregated in distinct terminal strobiles whose bracts differ widely from the foliage leaves. § 2. *Lepidotis.*

Foliage leaves 4–5-ranked, dimorphous; stems strongly dorsiventral. § 3. *Diphasium.*

§ 1. SELAGO

The northern types of this group are familiar in the boreal *Lycopodium Selago* and the more common *L. lucidulum* of the Northern States. *L. porophilum* is a more restricted and local plant somewhat intermediate between the other two species. The tropical representatives are more numerous, a very few simulating the northern species in habit, while a much greater number become epiphytic and are pendent from trees. The species * of meridional America may be separated as follows:

Plants with radial symmetry; leaves not twisted.
- Plants terrestrial in habit.
  - Leaves short, 1 cm. or less long.
    - Plants erect or ascending; leaves rigid.
      - Leaves in 16–20 ranks; stems short and rather stout.
        - Leaves serrulate, strongly hooked at the ends. 5. *L. densifolium.*
        - Leaves straight, with entire margins. 4. *L. Sieberianum.*
      - Leaves in 8 ranks, serrulate; stems elongate.
        - Leaves reflexed or loosely spreading.
          - Leaves verticillate, distant, closely coiling when dry. 3. *L. polycarpum.*
          - Leaves scattered, crowded, reflexed-spreading; sporangia 1.2 mm. wide. 1. *L. reflexum.*

* A number of the species from South America are omitted here, owing largely to lack of sufficient material. The following members of this group are more or less perfectly represented in the herbarium of the New York Botanical Garden in addition to the species tabulated below: *L. compactum* Hook., *L. rufescens* Hook., *L. erythraeum* Spring, *L. tetragonum* Hook., *L. crassum* H.B.K., *L. Hartwegianum* Spring, *L. filiforme* Sw.

Leaves rigid, thick, ascending; sporangia 1.8 mm. wide.
2. *L. rigidum.*

Plants spreading or pendent; leaves lax, somewhat secund.
9. *L. portoricense.*

Leaves longer, 1.5 cm.

Leaves linear, 0.6–0.8 mm. wide. 6. *L. montanum.*

Leaves lanceolate, 1 mm. wide. 7. *L. hippurideum.*

Plants epiphytic, pendent from trees.

Leaves short, 8 mm. or less long.

Plants with slender, many times dichotomous stems.

Plants 60 cm. or more long.

Strobiles compact; sporophyls short, triangular.
10. *L. Pringlei.*

Strobiles lax; sporophyls slender, subulate.
8. *L. setaceum.*

Plants short, under 20 cm. long; leaves very narrow, scattered, widely spreading. 20. *L. Williamsii.*

Plants with thick cord-like stems, closely dichotomous.

Leaves slender, flaccid. 17. *L. funiforme.*

Leaves broader at base, rigid. 16. *L. Picardae.*

Leaves larger, 1–3 cm. long.

Stems red, robust; leaves 2.5 cm. long, sharply reflexed from near the base. 12. *L. pithyoides.*

Stems green.

Leaves and sporophyls 4-ranked. 15. *L. nitens.*

Leaves and sporophyls 6–10-ranked.

Leaves rigid, closely appressed. 14. *L. cuernavacense.*

Leaves lax, spreading.

Leaves narrow, less than 0.5 mm. wide.
19. *L. Wilsonii.*

Leaves wider, 0.5–1 mm. wide; midrib prominent.
18. *L. dichotomum.*

Plants more or less dorsiventral by the twisting of the leaves.

Leaves sharply twisted at the base, usually narrowed below.

Plants short, 25 cm. or less long.

Stems short, dichotomous from near the base; leaves crowded, short and rigid; midribs prominent.
13. *L. Orizabae.*

Stems lax; leaves scattered, widely spreading, broadest at the middle, less than 1 cm. long; sporophyls similar. 23. *L. tenuicaule.*

Plants elongate, 35–80 cm. long; leaves lax, with less conspicuous midribs, long-tapering.

Leaves straight or slightly arcuate, 1.5–3 mm. wide, with inconspicuous midribs. 21. *L. linifolium.*

Leaves strongly arcuate, widely spreading, narrow (1 mm.), with conspicuous midribs; sporophyls short (8 mm.), slender.
22. *L. Jenmani.*

Leaves twisted throughout their entire length, widest at base.
11. *L. taxifolium.*

1. LYCOPODIUM REFLEXUM Lam. Encyc. Meth. Bot. **3**: 653. 1789. (Type from Martinique, *Martin.*)

Lycopodium squarrosum Sw. Nov. Gen. et Sp. Pl. 137. 1788.—Fl. Ind. Occ. **3**: 1571. 1806. (Type from Jamaica, and cites same plates as Lamarck.) Not *L. squarrosum* Forst. 1786.

Lycopodium reflexum Willd. Sp. Pl. **5**: 52. 1810. (Type from "Amer. merid."; apparently described independently by Willdenow, overlooking Lamarck's name.)

Lycopodium bifidum H. & B.; Willd. Sp. Pl. **5**: 53. 1810. (Type from "Amer. merid.")

Lycopodium eversum Poir. Encyc. Meth. Bot. Suppl. **3**: 556. 1813. (Based on *L. reflexum* Willd. not Lam.)

Lycopodium reversum Presl, Rel. Hænk. **1**: 82. 1825. (Type from Guayaquil.)

In the above long synonymy we have a hint of wide distribution and a considerable degree of variability, which was aggravated by the citation in Lamarck's original description of two plates that did not belong to the species, which he described as having reflexed leaves, viz.: Plumier, Fil. *pl. 166, f. A*, and Dillen, Hist. Musc. *pl. 57, f. 4*, which were later separated as a distinct species.

RANGE: Cuba (*Wright 933*), Porto Rico, Jamaica, Haiti (*Nash 557*), Guadeloupe (*Perrin*), Mexico, Guatemala (*J. D. Smith 504, Maxon 3560*), Colombia, Bolivia.

2. LYCOPODIUM RIGIDUM Gmelin, Syst. Nat. ed. 13. **2**: 1289. 1791. (Founded on Dillen, Hist. Musc. *pl. 57, f. 4.*)

This figure of Dillen represents the rigid form of the plant, which has often passed as *L. reflexum*. Dillen's figure according to his own statement is copied from Plumier (Fil. *pl. 166, f. A.*), so that by some *L. rigidum* might be regarded as a synonym of *L. reflexum* Lam.*

* In the whole matter of the determination of types a certain amount of plain ordinary common sense must be used. In this instance we have in the West Indies two closely allied plants whose imperfect original descriptions both cite the same plates. One plant has notably *reflexed* leaves while the other has *rigid* leaves. It was evidently this character in each case that suggested the names *reflexum* and *rigidum*. Lamarck clearly had the plant whose leaves are lax and consequently become reflexed as they mature. His plant, collected in Martinique by Martin, if in existence will serve as a type of his species. But he added to his description, citations from Plumier and Dillen drawn evidently from the species with rigid erect leaves, which Gmelin later

RANGE: Jamaica (*Wilson, Jenman, Underwood 181*), [Martinique?, *Plumier*]. This plant is apparently less common and less widely distributed than *L. reflexum.*

3. **Lycopodium polycarpum** (Sod.) sp. nov.
Lycopodium reflexum γ polycarpum Sod. Crypt. Vasc. Quitenses 569. 1893. (Type from Ecuador.)

A terrestrial plant with verticillate distant leaves 35–40 cm. high. Stem rather slender, 1.5 mm. or less thick, four times dichotomous, the ultimate divisions elongate; leaves and sporophyls distant, in nearly regular whorls, about 8-ranked, 4–5 mm. long by 0.8 mm. wide, linear-lanceolate, acute, serrulate, recurved, in drying bent back to form a semicircle; sporangia reniform, 1.5 mm. wide, laterally exceeding the sporophyls in width.

ECUADOR: 1899, *Sodiro* (type); *Spruce 4973.*

We have excellent specimens from Father Sodiro which show a relation to *L. reflexum* but are amply distinct as a species. The large sporangia coupled with the distant leaves make the former unusually prominent, a fact that is recorded in the name. The species is apparently most closely related to *L. intermedium* Spring, of which we have not seen the type, but in any case that name is antedated by *L. intermedium* Blume, by a number of years.

4. LYCOPODIUM SIEBERIANUM Spring, Monog. Lycop. 1: 23, *excl. syn.* 1842. (Type from Martinique, *Sieber 56.*)

Spring apparently confused with specimens of a very distinct species, various figures, some of which had already served as types of other species. On receiving a very distinct plant from St. Kitts we had thought at first to describe it as new on the strength of these citations, but on examination of *Sieber 56* at Berlin the past summer (the plant on which Spring based his name and in part his description) we find that our St. Kitts plant

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separated as *L. rigidum*, basing his description on Dillen's plate which was taken direct from Plumier. In the absence of type specimens there are many who would make the two names synonyms, and rename Gmelin's species. But to one familiar with both plants in the field the names *reflexum* and *rigidum* assume greater importance and significance. The liability of error in interpretation in the purely "literary revision" of plant names without the supplemental knowledge of the plants themselves, receives here a capital illustration, and all such revision is to be deprecated. Plain common sense would suggest the continuance of the two names accepted above as representing the spirit of the founders of the two species concerned.

agrees perfectly, so that it is necessary to retain Spring's name with an emended application. We have therefore drawn up a fresh description from a recently collected plant:

A stout terrestrial plant with 2–3 forks, and leaves crowded in about 20 ranks. Stems 20 cm. or more long; leaves 5 mm. long or more by 0.8 mm. wide at the base, entire, tapering to an acute apex, spreading, slightly ascending, curved dorsiventrally at the base and near the apex; sporangia reniform, exceeding the sporophyl in width by only a small amount.

MARTINIQUE: *Sieber 56* (specimens in herb. Berol.); *Hahn 1263* (specimens in herb. Kew).

ST. KITTS: Mt. Misery, among ferns, *Britton & Cowell 547*. Only a single plant was collected, but its characters are so strikingly different from *L. reflexum* and *L. rigidum*, its nearest allies, that we do not hesitate to take up Spring's name for it as representing a valid species. This plant is no doubt included by Baker in his description of *L. rigidum*, and Hahn's plant above cited was found under the cover of *L. rigidum* at Kew. We have not seen the plants from Peru and Chile, cited by Spring, so can give no details of its distribution further than recorded above. The habitat of the plant seems to be the volcanic craters of the Lesser Antilles. The exact locality of Sieber's plant is not recorded. Hahn's plant came from Mont Pelée and the St. Kitts specimen was found in the similar crater of Mt. Misery. It probably will be found on all the volcanic mountains of this group.

5. **Lycopodium densifolium** (Baker) sp. nov.

Lycopodium reflexum var. *densifolium* Baker, Handbook of Fern Allies 11. 1887.

A terrestrial plant 35 cm. or less tall, 2–4-dichotomous. Stems stout, 4–6 mm. or more in diameter exclusive of the leaves; leaves in about 20 ranks, crowded, 4–5 mm. long by 1 mm. wide at base, tapering from a point one fourth the length from the base to the acute mucronate apex which appears obtuse from above or below owing to the excessive curvature, stiff, spreading at right angles to the stem, strongly curved upward (or nearly hooked) at the apex, thickened dorsiventrally throughout the curve; margins with a few (1–5) short triangular multicellular straight or reflexed teeth near the base, and a few others more widely scattered throughout the length; sporangia broad, mostly confined to the upper portions of the stems.

ECUADOR: 1857–9, *Spruce 5429*. A unique species, with rigid leaves wholly unlike *L. reflexum*, under which name it was distributed. In the Kew Herbarium Mr. Baker has marked this number of Spruce as *L. reflexum* var. *densifolium*, a conclusion no one could have reached from Mr. Baker's brief description of the plant.

6. **Lycopodium montanum** sp. nov.

A terrestrial shade plant, 30–40 cm. high, with decumbent bases and dark-green foliage. Stems 2–3 mm. thick, once or twice forked, the older portions becoming decumbent and ultimately dying away while the newer parts are nearly erect, the whole stems often 70–90 cm. long with dark-green foliage; leaves 1.5 cm. long by 0.7–0.8 mm. wide, linear, acuminate, spreading, at length reflexed, downwardly curved near the tips, the midrib not evident in the dry material but distinct when moist; sporophyls like the leaves, the sporangia much exceeding the sporophyls in width, 1.5 mm. broad and nearly as deep.

JAMAICA: Summit of Blue Mountain Peak in deep shade, *Underwood 2537* (type), *2542*; *Nock* (in herb. Jenman).

Near to this species are the closely allied specimens from Bolivia (*Mandon 1528*) and Ecuador (*Sodiro*), which probably belong to *L. Lechleri* Hieron., a species recently described. *L. hippurideum* Christ is also a closely allied species.

This plant was apparently first collected in Jamaica by Nock in 1880 on the ridge of Blue Mountain Peak. Mr. Jenman confused this elegent terrestrial species with the epiphytic and remotely related *L. dichotomum*, and when the latter species was brought in from Grenada he was inclined to regard it as undescribed, as he had evidently not seen the true *L. dichotomum* from Jamaica, where it appears to be rather rare. The two species have very little in common and this elegant plant is one of the handsomest of the terrestrial species, growing in large patches in the shade of the dense forest that covers the summits of the Blue Mountain range.

7. LYCOPODIUM HIPPURIDEUM Christ, Prim. Fl. Cost. 3[1]: 56. 1901. (Type from Costa Rica, *Pittier 10619*.)

COSTA RICA: El Páramo, 3000 m., Massif de Buena Vista, *Pittier 10619*. Known only from its type locality. There is a cotype in the United States National Herbarium.

8. LYCOPODIUM SETACEUM Lam. Encyc. Meth. Bot. **3**: 653. 1789. (Type from the Antilles and Bourbon; but Plumier, Fil. *pl. 166, f. B*, as well as Dillen, Hist. Musc. *pl. 56, f. 3*, is cited.) Not *L. setaceum* Hamilton, 1825.

Lycopodium acerosum Sw. (Fl. Ind. Occ. **3**: 1575. 1806; type from Bourbon) may be the same species, since Swartz cites the same plates as Lamarck and states that Dillen also had it from the West Indies. Swartz in Syn. Fil. (1806) refers both *L. setaceum* and *L. acerosum* to *L. verticillatum* L. fil. (Suppl. 448. 1781; type from Bourbon), but this is described as having "*foliis quadrifariis*," which will not apply to the plant of the American tropics. Since the time of Swartz, the American plant has been referred to *L. verticillatum*, probably incorrectly; at least the name *L. setaceum* is the earliest that it is safe to take up in the absence of any material from Bourbon.*

RANGE: Cuba (*Wright 935, Eggers 5173*), Jamaica (*Jenman*), Martinique (*Père Duss*), Haiti (*Nash 664*), Dominica (*Lloyd 342, 697, 808, 810*).

9. **Lycopodium portoricense** sp. nov.

A bushy but slender pale-green terrestrial pendent plant with subsecund leaves. Stems less than 1.5 mm. in diameter, covered to the bases with leaves, several times dichotomous, 30 cm. or more long; leaves and sporophyls alternating in zones, the leaves linear, acuminate, 6–8 mm. long by 0.3–0.4 mm. wide, more or less secund; sporophyls tapering gradually from a base 0.6 mm. wide to the apex, 6 mm. long; sporangia round-reniform, 1.3 mm. wide by 1 mm. deep.

PORTO RICO: Road from Guyama to Cayey, pendent on banks, *Underwood & Griggs 434* (type); Luquillo Mts., *Percy Wilson 141*.

This species is related rather closely to *L. setaceum*, but differs in its longer leaves, which are truly linear and not tapering from the base, in its larger stems, and in its terrestrial habit.

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*Since the time of Swartz it has been quite common to refer West Indian and Central American pteridophytes to species originally described from Bourbon (Réunion) or Mauritius. When we come to examine typical material from those islands we invariably find it very different from the better known American forms referred to the same species. There is every *a priori* reason for supposing the two floras to be very distinct, and every new examination of pteridophyte types shows this supposition to be true.

10. **Lycopodium Pringlei** sp. nov.

Epiphytic, pendulous, of slender open habit; stems 40 cm. or more long, about five times dichotomous, appearing cord-like from the appressed leaves; leaves subulate, 2.5–3 mm. long, 0.6 mm. wide, about 6-ranked; strobiles more or less interrupted, the shoots becoming variable in thickness because of the large crowded sporangia; sporophyls triangular, entire, 1.3 mm. long or less, 0.8 mm. wide at base, exceeding the sporangia only by their short apices, appressed except when distended by the ripened sporangia; sporangia nearly circular, 0.8 mm. wide by 0.6 mm. deep, sometimes slightly protruding beyond the margins of the sporophyls.

MEXICO: Hanging from oaks, Sierra de Clavellinas, 9000 ft., Oaxaca, *Pringle 4994* (type); Orizaba, *Müller 361*. A plant collected at Morelos, *Rose 4416*, is either this or very closely allied.

The plant was distributed by Pringle as *L. verticillatum*, but does not show close relationship to any of the West Indian plants bearing that name or that have been referred to that species. It is a much smaller-stemmed plant than *L. nitens*, and has 6-ranked instead of 4-ranked leaves and sporophyls as in that species.

11. LYCOPODIUM TAXIFOLIUM Sw. Nov. Gen. et Sp. Pl. 138. 1788.—Flor. Ind. Occ. **3**: 1573. 1806. (Type from Jamaica; in the latter work Swartz also says "*etiam in insula St. Helena.*")

While there is very great variation in the length of the leaves, often resulting in the appearance of much more slender stems, we cannot distinguish among the specimens from the West Indies the *Lycopodium passerinoides* H.B.K. (Nov. Gen. **1**: 41. 1815), the type of which was from Peru, and quite likely represents a plant widely different from the West Indian things that in recent years have been referred to it.

RANGE: Cuba, Hispaniola, Porto Rico, Jamaica, Dominica, St. Vincent, Grenada, Mexico, Colombia.

12. LYCOPODIUM PITHYOIDES Schlecht. & Chamisso, Linnaea **5**: 623. 1830. (Type from Jalapa, Mexico, *Schiede & Deppe.*)

MEXICO: Santa Maria, *Schaffner*; Orizaba, *Müller 691*.

GUATEMALA: *Seler 2329*.

CUBA: Santiago, *Hamilton 247*.

This characteristic species, long neglected or overlooked at Kew, is so clearly defined that one wonders at the oversight.

The plant from Cuba, though a fragment, is unmistakable, and shows an unexpected and unusual distribution.

13. **Lycopodium Orizabae** sp. nov.

A short rather stout epiphyte 16 cm. or more tall, with abundant lanceolate leaves. Stems 2–3 mm. thick at the base, more slender above, 3–4 times dichotomous, rising from dense clusters of roots; leaves 1.5–1.8 cm. long by 2–2.3 mm. wide, lanceolate-acuminate, broadest near the base, thence abruptly narrowed at the base, asymmetric, the midrib slender but evident almost to the apex, the margins entire; sporophyls similar to the leaves, but shorter and narrower, 1 cm. long by 1 mm. wide, lanceolate, broadest near the middle, acuminate, twisted at the base, slightly asymmetric; sporangia reniform, 1.8 mm. wide by 1.5 mm. deep.

MEXICO: Orizaba, *Müller 690*. Known only from its type collection.

14. **Lycopodium cuernavacense** sp. nov.

An elongate rigid epiphyte, with stiff appressed leaves. Stems attaining 60 cm. or more long, 3–4-forked, the branches diverging at a very small angle, rather stout, 3–4 mm. thick; leaves crowded, somewhat appressed, rigid, 2 cm. long by 2 mm. wide, subulate-acuminate, broadest at the base, the midrib evident by a furrow when dry, the margins entire; sporophyls similar to the leaves but shorter, about 1 cm. long; sporangia circular, slightly exceeding the sporophyls in width.

MEXICO: Morelos; trees in mountains above Cuernavaca, 8,500 ft., *Pringle 7613*.

This species is related to *L. taxifolium*, for which it was distributed, but differs from that species both in habit and in structural characters.

15. LYCOPODIUM NITENS Schlecht. & Chamisso, Linnaea **5**: 623. 1830. (Type from Jalapa, Mexico, *Schiede & Deppe*.)

Of this species we have seen only an original specimen, a sheet of which is at Kew. Its four-ranked leaves and sporophyls render it a striking plant.

16. LYCOPODIUM PICARDAE Christ, Bot. Jahrb. **24**: 148. 1898. (Type from Haiti, *Picarda 978*.)

We have a portion of the original collection made in 1892 (*Picarda 978*) whose label reads "Haiti prope Keurcoff in caverna, alt. 1,200 m."

17. LYCOPODIUM FUNIFORME Chamisso; Spring, Monog. Lycop. 1: 50. 1842.

The name was given by Chamisso to a plant in herb. Bory which was marked "California"; to this Spring in publishing the description added "Guadeloupe, *L'Herminier*" which should be regarded as the type locality. The plant is a well known Antillean species and the "California?" was evidently a mistake as the plant is apparently endemic in the West Indies.

RANGE: Cuba (*Wright 943*, *Pollard & Palmer 168*, *Underwood & Earle 658*, *1033*), Porto Rico (*Heller 1084*, *Percy Wilson 102*), Guiana (*Jenman*).

The living plant is well named, as the resemblance to cordage is very striking.

18. LYCOPODIUM DICHOTOMUM Jacq. Hort. Bot. Vind. **3**: 26. *pl. 45*. 1776. (Type from Martinique.)

RANGE: Cuba (*Wright 944*), Hispaniola (*Nash 680*), Jamaica (*Clute 64*), Dominica (*Lloyd 506*, *798*, *809*, *819*), St. Kitts (*Britton & Cowell 304*), Grenada (*Sherring*), Guadeloupe (*Dr. Madiana*), Martinique, St. Vincent (*Smith 735*), Mexico (*Schaffner 3*, *Pringle 3976*), Guiana (*Jenman*).

There is some degree of variation present in this species. We were at first inclined to separate the St. Kitts plant as distinct and with it would go the scrap from Guadeloupe here cited from the Torrey herbarium. As noted above, Mr. Jenman confused the plant which we have described as *L. montanum* with this species, and then in his herbarium referred the Grenada plants really belonging here to a new name, *L. grenadense* Jenm. It is probably more logical to consider all the forms as coming under a single species.

19. **Lycopodium Wilsonii** sp. nov.

A small epiphyte with divergent forking branches and slender leaves. Stems 8–15 cm. long, about 2 mm. thick, with about three forks, the branches divergent; leaves linear, 1.5–1.8 cm. long by 0.6 mm. wide, very gradually tapering from the base to the acuminate apex, symmetrically or slightly curved; sporophyls similar to the leaves, but smaller, 1 cm. long by 0.4 mm. wide; sporangia round-reniform, 1.5 mm. wide by 1.3 mm. deep, exceeding the sporophyls in width.

PORTO RICO: Luquillo Mountains, *Percy Wilson 271* (type), *153*.

This species is perhaps nearest to *L. dichotomum*, varying in the direction of *L. setaceum*, but widely different from either in habit and structure. We dedicate it to its enthusiastic collector, whose visit to Porto Rico was productive of several novelties in the genus *Lycopodium*.

20. **Lycopodium Williamsii** sp. nov.

A small slender much-branched epiphyte 10–15 cm. long. Stems slender, pendulous, less than 1 mm. thick, sparsely covered with foliage below, hidden by the copious sporangia above; leaves scattered, slightly curved, widely spreading or descending, 7–9 mm. long by 0.5 mm. wide, linear, acute, with entire margins; sporophyls shorter, 4–6 mm. long by 0.3 mm. wide, linear; sporangia round-reniform, prominent, relatively large, 1 mm. wide by 0.8 mm. deep.

BOLIVIA: New Brazil, 5,500 ft., *Williams 1393*.

This beautiful moss-like species was collected by Mr. R. S. Williams on the Conway expedition in 1902, and we are pleased to recognize his discriminating field-work which shows itself in most beautifully prepared specimens, a form of work only possible when a trained botanist is sent to the field, and is not hampered by the necessity of collecting "sets of plants" for commercial or exchange purposes.

21. LYCOPODIUM LINIFOLIUM L. Sp. Pl. 1100. 1753. (Type from "Amer. merid." based on Dillen, Hist. Musc. *pl. 57, f. 5*, and Plumier, Fil. *pl. 166, f. C.*)

RANGE: Cuba, Hispaniola (*Nash 195* *), Porto Rico, Jamaica, Grenada, Trinidad, Mexico, Guatemala, Colombia, Venezuela, Guiana, Bolivia.

22. **Lycopodium Jenmani** sp. nov.

A slender pendent much-branched epiphyte with attenuate branches. Stems very slender, 1 mm. thick, much branched, with

* These specimens collected by Mr. Nash are simply superb developments of this beautiful species, the multitudinous branches of a bushy plant rising from a single stem all represented on the sheet, and strikingly in contrast with the old-fashioned "tips" of branches that constitute too many of the herbarium specimens of a past generation. Such specimens as these really give one some idea of the habit and true character of the living plant.

scattered leaves and contracted sporophyls; leaves arcuate, lanceolate, acuminate, 1–1.3 cm. long by 1–1.2 mm. wide, unsymmetrical, the midrib nearer one margin, widely spreading, distinctly curved, twisted at the base so that the blade lies in the plane of the axis; sporophyls twisted like the leaves, linear, much smaller at the ends of the branches, but ultimately attaining the size of the smaller leaves; sporangia reniform, 1.5 mm. wide by 1 mm. deep, much exceeding the leaves in width and thus appearing very conspicuous in the mass of foliage.

BRITISH GUIANA: Moruca River, *Jenman*.

Mr. Jenman had marked this plant in his herbarium as a distinct variety of *L. linifolium*, but the name assigned being untenable as a specific name in the genus, we are pleased to dedicate it to the memory of this most assiduous of students of the pteridophytes of the British colonies in America, whose collection and critical notes and publications add so much to our exact knowledge of the tropical pteridophyte flora of America.

23. **Lycopodium tenuicaule** sp. nov.

A lax slender epiphyte with delicate scattered leaves. Stems springing from a small cluster of roots, 20–30 cm. long, loosely branched, smooth, 1 mm. thick, the shoots dorsiventral by the twisting of the leaves at their bases; leaves 7–9 mm. long by 1.5 mm. wide, lanceolate, broadest at the middle or just above, acute, slightly unsymmetric, entire, twisted at the base so as to bring the blade to the plane of the axis, widely spreading, scattered, all sporangiate except on the oldest part of the stem; midrib slender, scarcely evident beyond the middle of the leaf: sporangia reniform, 1.3 mm. wide by 1 mm. deep.

DOMINICA: Mt. Diablotin, *Lloyd 878* (type).

PORTO RICO: Luquillo Mountains, *Percy Wilson 139*.

This delicate and graceful species which has appeared from two rather distant and distinct stations is very unlike any other West Indian species, forming a peculiar type with no near congeners.

§ 2. LEPIDOTIS

The tropical American species of this section fall somewhat naturally into four groups which are widely separated from each other in habit. We may separate these groups synoptically as follows:

Species epiphytic, pendent from trees; leaves dorsiventral. **Phlegmaria Group.**
Species of terrestrial habit.
  Stems erect, usually naked at the base; habit tree-like. **Cernuum Group.**
  Stems creeping.
    Stems wide, trailing, with ascending branches. **Clavatum Group.**
    Stems short, prostrate, with simple monostachyous branches. **Iuliforme Group.**

PHLEGMARIA GROUP

This group with strongly dorsiventral leaves is largely represented in South America, but one of the species extends into the West Indies. They may be separated as follows:

Leaves broadly oval or obovate.
  Leaves small, 3.5 by 2.5 mm.; sporophyls scarcely exceeding the sporangia.
    Leaves narrowed (cuneate) at the base. 24. *L. cuneifolium.*
    Leaves rounded at the base. 25. *L. callitricaefolium*
  Leaves larger, 6–8 by 3–5 mm.; sporophyls extending into a point beyond the sporangia.
    Sporophyls long, often attaining 20–40 cm.; leaves mostly regular. 26. *L. aqualupianum.*
    Sporophyls short, 1–2 cm.; leaves obtuse or nearly so, irregularly spreading. 27. *L. dichaeoides.*
Leaves lanceolate or lanceolate-ovate.
  Leaves 2 mm. or more wide; sporophyls extending beyond the sporangia into a long point. 29. *L. roraimense.*
  Leaves under 2 mm. wide; sporophyls shorter than the sporangia. 28. *L. subulatum.*

24. LYCOPODIUM CUNEIFOLIUM Hieron. Bot. Jahrb. **34**: 572. 1905. (Type from Costa Rica, *Hoffmann 50.*)

COSTA RICA: Vulcan de Barba, *Hoffmann 50;* with no locality, 1900, *C. Wercklé.* A plant nearly allied to *L. callitricaefolium* but readily separated by its more distant narrowly obovate leaves.

25. LYCOPODIUM CALLITRICAEFOLIUM Mett. Ann. Sci. Nat. V. **3**: 309. 1865. (Type from Bogota, Colombia, *Triana.*)

RANGE: Ecuador (*Spruce 4792, Sodiro*), Colombia, Costa Rica (*Warscewicz 12.*)

26. LYCOPODIUM AQUALUPIANUM * Spring, Monog. Lycop. **1**: 68. 1842. (Type from Guadeloupe, *L'Herminier*, and Hispaniola, *Neckour.*)

* This name is probably a misprint for *guadalupianum* to which form Fée changed it in 1866; Urban (1903) writes it "*guadeloupeanum.*" We retain the original orthography as safer.

RANGE: Cuba (*Wright 936, Eggers 5165*), Porto Rico (*Sintenis 1546, Percy Wilson 155*), [Hispaniola, Guadeloupe], Bolivia (*Rusby 458*). The last named plant is sterile but cannot be separated by its foliage; it is distinct from *Mandon 1529*, which is *L. subulatum*.

27. LYCOPODIUM DICHAEOIDES Maxon, Proc. Biol. Soc. Washington **18**: 231. 1905. (Type from Guatemala, *Cook & Griggs 251*.)

GUATEMALA: Alta Verapaz, near Sepacuité, *Cook & Griggs 251*; between Sepacuité and Secanquim, *Maxon & Hay 3268*. Known only from these two collections now in the United States National Herbarium.

28. LYCOPODIUM SUBULATUM Desv. Encyc. Bot. Suppl. **3**: 544. 1813. (Type from "Amer. merid.")

Represented in typical form in the herbarium of the New York Botanical Garden only by sheets of *Mandon 1529* from Bolivia. There are numerous variations, some of which have been described by Baker. Among these are two sheets from Ecuador collected by Sodiro, which are marked "var. *pastoense*," which differ from each other and must be compared with Baker's type before they can be definitely placed. They probably represent one or more distinct species.

29. **Lycopodium roraimense** sp. nov.

A long slender pendulous epiphyte with sporophyls much longer than the sporangia. Stems over 75 cm. long, 2–3 forked, dorsiventral (except in the sporophyllary region) by the twisting of the leaves, the strobile elongate (30 cm.) and radially symmetrical; leaves lanceolate-ovate, acute, 8–9 mm. long by 2.5 mm. wide, twisted at the base, entire, thin, the midrib slender but distinct; sporophyls triangular, small, 1.5–3.5 mm. long by 1–1.5 mm. wide, extending beyond the sporangia in a point, the margins entire; sporangia conspicuous, nearly circular, exceeding the sporophyls in width.

BRITISH GUIANA: Forest slopes near Roraima (*herb. Jenman*). This plant differs from *L. subulatum*, its nearest ally, in its wider leaves and much longer sporophyls.

CERNUUM GROUP

The species of this group have a close relationship among themselves and are quite isolated from other related species.

Baker,* with characteristic disregard of continental work, reduces all the species involved, to *L. cernuum*, with three varieties, in which citation and synonymy are sadly at variance with accuracy and correctness, and all ideas of geographic distribution are left to reckless abandon.

In 1861 Müller,† with characteristic German positiveness, set aside a Javan plant as the genuine type of *Lycopodium cernuum* L., characterized by having (1) "*Folia caulina squarrosa*" in common with most other species recognized, and (2) "*Amentis centripetali-evolutis*," a character claimed as peculiar to this species, but one difficult to follow in actual material. Further than this he established five new species all from the Old World, besides recognizing *L. marianum* Willd. from the Philippine Islands. The distribution of his five new species was as follows:

Lycopodium Heeschii K. Müll. (*loc. cit.* 164) — Sierra Leone.
Lycopodium secundum K. Müll. (*loc. cit.* 164) — Cape Colony, Natal.
Lycopodium sikkimense K. Müll. (*loc. cit.* 164) — Sikkim (India).
Lycopodium Moritzii K. Müll. (*loc. cit.* 165) — Java.
Lycopodium Hupeanum K. Müll. (*loc. cit.* 165) — Borneo.

In Müller's paper the species of tropical America were not considered, and two earlier descriptions from the Old World were apparently disregarded, *viz*:

Lycopodium vulcanicum Blume, Enum. Pl. Jav. **2**: 266. 1828. (Type from Java.)

Lepidotis convoluta Beauv. Prodr. L'Aetheog. 108. 1805. (Type from "Les deux Indes.") Material in American collections is insufficient to determine the status of Müller's species, but a partial examination of European herbaria convinces us that some of them at least are valid.

Hieronymus has recently ‡ taken up the name *Lycopodium capillaceum* Willd. for the common American species, citing Spring's reference to Willdenow's herbarium note § and stating that Willdenow's plant was from "Nova Andalusia" (Venezuela) instead of "Ins. Marianis" as stated by Spring. After seeing

* Handbook of Fern Allies 23. 1887.

† MÜLLER, KARL. Zur Kenntniss des *Lycopodium cernuum* L. Bot. Zeitung **19**: 161–165. 1861.

‡ Plantae Lehmannianae etc. Bot. Jahrb. **34**: 573. 1905.

§ Flora **21**[1]: 165. 1838.

Ceylon material (for we must regard the Ceylon plant as the type of *Lycopodium cernuum*) in various European collections, commencing with that of Linnaeus at London, we are unable yet to point out differences other than minor ones between the plants of Ceylon and those of the West Indies. We are compelled against our tendencies to retain the name *cernuum* for the common species of the American tropics. Hieronymus has also separated two additional South American species, neither of which affect those which had been already separated by us.

The four species from America which we have examined may be separated as follows:

Leaves toothed; axes bristly; strobiles elongate (1.5–4 cm.). 31. *L. curvatum.*
Leaves entire; axes mainly smooth.
  Strobiles short (1 cm. or less), with deeply ciliate-laciniate sporophyls; branches slender. 30. *L. cernuum.*
  Strobiles longer (1.5–2 cm. or more); sporophyls slightly toothed; branches stout.
    Sterile branchlets elongate (5–10 cm.) and pendulous; leaves short and abruptly narrowed. 33. *L. pendulinum.*
    Sterile branchlets short, stout, dichotomously spreading; leaves longer, gradually tapering. 32. *L. tortum.*

30. LYCOPODIUM CERNUUM L. Sp. Pl. 1103. 1753. (Type from "Indiis"; the bulk of the citations commencing with Linnaeus' own Fl. Zeyl. and Dillen indicate that the East India plant is the one which represents the plant as known to Linnaeus and his predecessors. Plumier, Fil. *pl. 165 A* is cited later as an example of an American plant.*)

RANGE: (In America only) Georgia, Florida, Alabama, Mississippi, Cuba, Hispaniola, Porto Rico, Jamaica, S. Thomas, St. Kitts, Guadeloupe, St. Vincent, Dominica, Trinidad, Mexico, Panama, Colombia, Guiana.

31. LYCOPODIUM CURVATUM Sw. Syn. Fil. 178, 402. 1806. (Type from Jamaica.†)

* As noted above this plant is the one to be renamed in case the American plant is ever distinguished from that of Ceylon.

† In publishing this species Swartz cites in synonymy (*loc. cit.* 178) *Lycopodium arboreum* Gmel. (a name apparently unpublished) and *Lepidotis convoluta* Beauv., a plant imperfectly described in Prodr. L'Aetheog. 108 (1805) from "Les deux Indes." Later (*loc. cit.* 402) Swartz in giving a fuller description cites Jamaica as the definite type locality. We cannot say whether *Lepidotis convoluta* Beauv. is distinct or not, but Swartz's type at least is Jamaican.

JAMAICA: Salt Hill (a mile off the Content road from Gordontown to Cinchona), growing in deep *Sphagnum*, 1903, *Underwood 157*.

The above collection represents, so far as known, the only one made in Jamaica since the time of Swartz. The fine material collected indicates a species abundantly distinct from that common in the vicinity on dry banks.

32. **Lycopodium tortum** Sieber, sp. nov.

A robust much-branched terrestrial plant with long pendent strobiles. Stems erect or ascending, a meter or more high, the secondary branches spreading, triangular in outline, attaining 20 cm. broad by 15 cm. high, repeatedly branched, the terminals inclined irregularly downwards and bearing the sessile strobiles; leaves on the older axes 5 mm. long by 0.5 mm. wide (on younger axes as short as 3 mm.) curved upwards and outward, becoming less curved and more widely spreading on the older axes, the curve commencing at about the middle, and the leaf tapering from above the middle to form an acute apex; margins entire; strobiles 1.5–2 cm. long, 3–4 mm. in diameter, cylindric or slightly angulate at the apex; sporophyls appressed, widely spreading, and but little curved when dry, 2.5 mm. long by 1 mm. wide, the margins irregular, with small scattered uneven teeth.

RANGE: Higher (volcanic) summits of the Lesser Antilles; specimens have been examined as follows:

ST. KITTS: Mt. Misery, *Britton & Cowell 550*.

GUADELOUPE: Mt. Perrin (*herb. Torrey*); 1898 (*herb. Jenman*).

DOMINICA: In old crater near Boiling Lake, Laudat, *Lloyd 315*.

MARTINIQUE: 1897 (*herb. Jenman*); *Sieber, Fl. Mixta 328* (*herb. Kew*).

ST. VINCENT: *H. H. & G. W. Smith 52*.

This species was long ago issued by Sieber under the above name, which in deference to him we have here taken up for the coarse plant of striking habit concerning whose distribution we have now quite definite information. In St. Kitts the species is locally known as "Stag Horn." This plant has been confused with *L. curvatum* Sw., the type locality of which (Jamaica) is quite outside the range of the peculiar species of the volcanic islands.

A second species allied to the last was collected in 1902 by Percy Wilson in the Luquillo Mountains, Porto Rico (*no. 101*), but the specimens are unfortunately in the vegetative condition

only; it differs from this species in its much smaller size and in its strongly incurved leaves which are hairy on the lower surface near the base and often toothed. Mature strobiles are a desideratum.

33. LYCOPODIUM PENDULINUM Hook Ic. Pl. 1: *pl. 90.* 1837.* (Type from Casapi, Peru, *Mathews 1776.*)

RANGE: [Peru]; Cargadira, Bolivia, 8000 ft., *Williams 1386.* Mr. Williams' specimens show a unique plant, widely distinct in habit from any others of the group.

CLAVATUM GROUP

It is a difficult problem to distinguish many of the species of this group, a large proportion of which Baker reduces to the single species *L. clavatum*, whose distribution is curiously given as "Arctic and alpine zones of both hemispheres, also mountains of tropical Asia, Africa and America, Cape, Mascaren [*sic*] Isles and Polynesia." In Jamaica a form occurs from 5000 ft. upwards to the very summit of the Blue Mountains which at present we are not able to separate on structural grounds from our common northern species,† although it differs *toto coelo* in habit. In place of our unobtrusive close-creeping plant, the Jamaican form is rampant in great masses over the paths about the Cinchona plantation, forming a weed, and sprawling over low shrubs in the greatest profusion. Material from the whole world will be needed to elucidate the relations of the species involved in this polymorphic tangle. Besides abundant material from Jamaica we have imperfect collections from Mexico, Guatemala, Colombia, Guiana, Brazil, Ecuador and Bolivia, but insufficient for monographic purposes. For these reasons we prefer to leave the Jamaican plants for the present under

34. LYCOPODIUM CLAVATUM L. Sp. Pl. 1101. 1753. (Type from Europe).

RANGE: Europe and North America from the Arctic zone as far as Pennsylvania; also (provisionally) Jamaica above 5000 ft., and possibly Mexico and Guatemala.

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* *L. Eichleri* Fée, Crypt. Vasc. Bres. *pl. 106. f. 4*, cited by Baker as a synonym, is apparently distinct if Fée's plate is to be relied on, and his plates are usually extremely reliable. Mr. Baker further cites this species incorrectly as *L. pendulum.*

† With a distribution scattered well over the Northeastern States extending as far west as Washington State and Southward to Pennsylvania, this species is far from being either "arctic or alpine" in America, although it does attain both these regions in this country as in Europe.

IULIFORME GROUP

35. **Lycopodium iuliforme** sp. nov.

A low plant with short close-creeping stems and rigid upright monostachyous branches. Creeping stems 6–10 cm. long or more, with numerous roots throughout; leaves in 10 or more ranks, those of the lower surface pale, narrow, and somewhat lax, 2–2.5 mm. long, triangular-subulate from a wider base, those of the lateral surfaces ascending, twisted, 3–5 mm. long, somewhat rigid, ending in a firm acuminate point; erect branches terminal, or becoming apparently lateral from the innovating branches of the prostrate stems, 9–12 cm. high, leafy throughout, the leaves mostly 8-ranked, rather rigid, slightly spreading, 4–5 mm. long, lanceolate-acuminate; strobiles 3–3.5 cm. long, slightly thicker than the stems; sporophyls 8-ranked, lanceolate above from a broad base, the rigid apices wide-spreading; sporangia reniform, 1.5 mm. wide, entirely concealed by the broad base of the sporophyls.

GUIANA: Summit of Roraima, 8,600 ft., *McConnell & Quelch 572*. (Type at the New York Botanical Garden.)

A unique species forming a series of its own, intermediate in a way between the *Inundatum group* and the *Carolinianum group*. It was reported upon by C. H. Wright (Trans. Linn. Soc. II. **6**: 87. 1901) as *L. contiguum* Kl., with which it has only a remote alliance. *L. contiguum* has membranous-tipped leaves and sporophyls, the latter soft, lax, and wide spreading, and with conspicuously erose margins.

§ 3. DIPHASIUM

The members of the section *Diphasium*, which forms a physiological rather than a structural alliance, will group themselves somewhat naturally as follows:

Vertical stems simple; foliage shoots prostrate, creeping, the leaves of the two under rows larger and appearing lateral. **Carolinianum Group.**

Vertical stems much branched.

Terminal foliage shoots with 4 rows of dimorphous leaves; upper surface with one row of leaves. **Complanatum Group.**

Terminal foliage shoots with 5 (or 6) rows of leaves, the upper surface with three rows of reduced leaves. **Scariosum Group.**

CAROLINIANUM GROUP

The species of this group were referred by Baker to our familiar *L. carolinianum* of the Southern States, but will readily separate themselves into at least three species as follows:

Sporophyls serrulate; under leaves triangular, nearly as broad at base as long; sporangia round-renate. 36. *L. goyazense.*

Sporophyls entire.

Sporangia depressed-renate; under leaves ovate, acute. 37. *L. meridionale.*

Sporangia round-renate; under leaves lanceolate. *L. carolinianum.*

36. **Lycopodium goyazense** sp. nov.

A small creeping plant with stout erect branches bearing large strobiles. Creeping stems 6 cm. or more long, notably dorsiventral, producing occasional short branches; leaves strongly dimorphic, those of the two under rows appearing lateral, triangular, symmetric, 2 mm. wide at the base, not contracted, 2.5 mm. long, acute, entire, thick, somewhat imbricated; those of the three upper rows small, triangular, twice as long as broad or more, stiff, remote from each other and thus exposing the broad upper surface of the stem; erect branches (peduncles) 7–9 cm. long, 1.5 mm. thick, with triangular scale-like leaves which are 4 mm. long by 1.5 mm. wide at base and serrulate; strobiles 3–4 cm. long, stout; sporophyls larger than the lateral leaves, 2.5 mm. wide by 5 mm. long, ovate, acuminate, not contracted above the middle; margins serrulate throughout.

BRAZIL: Goyaz, *Glaziou 22644;* also less perfect specimens from Minas Geraes, *Claussen.*

37. **Lycopodium meridionale** sp. nov.

A small close-creeping, sparingly branched plant with solitary upright strobilary branches. Creeping stems up to 40 cm. or more long, 1–1.5 mm. thick, with occasional short (2–4 cm.) lateral branches; leaves strongly dimorphic, those of the two under rows appearing lateral, 5 mm. long by 2 mm. wide, ovate, acuminate, falcate, the midrib curved asymmetrically and parallel to the proximal leaf-margin; leaves of the upper four rows subulate, spreading, 3.5 mm. long by 1 mm. wide; upright branches (peduncles) 8–26 cm. long, oftener rising from the short prostrate branches, with whorls of subulate spreading scale-like leaves with parallel margins or slightly contracted below the middle, entire or slightly erose near the base; strobiles 2.5–8 cm. long; sporophyls 2 mm. wide by 4 mm. long, triangular, contracted at the middle and subulate above, spreading, the margins entire above, erose below the middle, those of the same level not contiguous.

RANGE: Probably widely distributed through the tropics of meridional America. Specimens have been examined as follows:

PORTO RICO: Dry savannahs, Luquillo Mountains, *Percy Wilson 94* (type) (two sheets); *Sintenis 1544.*

CUBA: *Wright 1819.*

DOMINICA: Laudat, high wet turf, Boiling Lake, *Lloyd 316.*

GUIANA: Wet ground, Essequibo, *Jenman* (two sheets).

BRAZIL: San Carlos and Rio Negro, *Spruce 3039*; Moritiba, *Blanchet 3470.*

(LYCOPODIUM CAROLINIANUM L., ranging from New Jersey to Texas, is not found outside of the Southern States, and is introduced in the above synopsis for comparison only.)

COMPLANATUM GROUP

The only member of this group in the West Indies we described from herbarium material before having seen the plant in the field. Like *L. clavatum* of another group, *L. Fawcettii* forms a weed in the paths of the Cinchona plantation and grows luxuriantly, ascending over bushes and low shrubbery in a sprawling fashion and is thus quite in contrast with its more modest congeners of the Northern States. The status of *L. thyoides* H.B.K. of South America still remains to be determined. Our single West Indian species is

38. LYCOPODIUM FAWCETTII Lloyd & Underw. Bull. Torrey Club **27**: 167. 1900. (Type from Jamaica.)

This species is common in Jamaica from 5000 feet altitude to the extreme summit of the Blue Mountains. It has also been found in Hispaniola (*Wright, Parry & Brummel 37; Picarda 767; Eggers 2270*).

SCARIOSUM GROUP

The members of this group are mostly from tropical or south temperate regions. *Lycopodium scariosum*, with which Baker has confused the American species, is from New Zealand, and there are other Old World species. The American species are mostly South American, only a single species reaching Jamaica in the West Indies. The American species may be separated as follows:

Lateral leaves of the dorsiventral branches directed upwards, straight, rigid, tapering from the base, not sharply pointed nor crowded. 39. *L. Gayanum.*

Lateral leaves of the dorsiventral branches curved downwards.

Leaves ascending, cuspidate, strongly revolute. 42. *L. Holtoni.*

Leaves spreading, slightly curved.

Lateral leaves broad near the apex, obtuse. 40. *L. lindsaeaceum.*

Lateral leaves broadest at the decurrent base. 41. *L. Jussiaei.*

39. LYCOPODIUM GAYANUM Remy*; Gay, Hist. Chile Bot. **6**: 545. 1853. (Type from Chile, *Gay*.).

A single specimen in the Meissner (Columbia) herbarium from Valdivia, Chile, *no. 208* of "Bridges or Cuming?" represents this species in our collections as described, and shows characters warranting us in maintaining it.

40. LYCOPODIUM LINDSAEACEUM Spring, Flora **21**: 180. 1838. (Type from Peru.)

This species was united by Baker with the New Zealand *L. scariosum*, which naturally has little to do with the new world representatives of the group. The species is represented in the herbarium of the New York Botanical Garden by a single specimen collected by Rusby in Bolivia, and by several more recently brought from the same country by Williams.

41. LYCOPODIUM JUSSIAEI Desv. Encyc. Bot. Suppl. **3**: 543. 1813. (Type from Peru.)

We have specimens of this species collected by Spruce and Sodiro in Ecuador and were inclined for a time to separate Jamaica specimens collected by Purdie and by Jenman and more recently by Underwood and by Maxon. Jamaica material shows a marked differentiation in texture, the leaves being thinner, more distant, acute rather than mucronate, and inequilateral, *i. e.*, with the midrib nearer the anterior leaf-margin. In Jamaica the species is rare, growing at altitudes above 5000 feet. Baker (*loc. cit.*) reduced the species to a variety of *L. scariosum* of the Old World.

42. **Lycopodium Holtoni** sp. nov.

Main stems creeping, sending up lateral shoots 25 cm. or more tall, with foliage shoots ending in bifid peduncles; lateral (upper) leaves of the dorsivental ascending branches crowded and imbricate, ascending, the lateral free margin revolute (so that the leaf appears strongly twisted in the dry condition), the upper surface arched, thick, coriaceous, cuspidate; ascending shoots 3–8 mm. wide, varying in diameter throughout the length; leaves of the under three rows 4–5 mm. long, 1.5 mm. wide at the base, awl-shaped, thin, scarious-margined and often slightly lacerate, the apices scarious or hair-like; strobiles 5–6 cm. long, 5 mm.

*This species is usually referred to Remy and it is not likely that Gay would name a species after himself, but we have failed to find in this volume any evidence that Remy described this species.

thick, appearing ridged by the somewhat carinate sporophyls; sporophyls ovate, acuminate with a scarious lacerate tip and a narrow (1 mm.) claw, 5 mm. long, by 2.5 mm. wide, the margin slightly erose; sporangia depressed-triangular, 3 mm. broad by 1.75 mm. deep, folded and irregular, sessile.

COLOMBIA: In montibus juxta Bogotam, 7 Oct. 1852, *I. F. Holton 79.**

Unless otherwise noted all the above citations of specimens are from the combined herbaria of Columbia University and the New York Botanical Garden, now forming a single collection.

COLUMBIA UNIVERSITY.

* The extensive collection of Isaac F. Holton was one of the first made in Colombia and has never been studied; a full set of the collections is in the Torrey herbarium; Holton went out from Middlebury College on a twenty months' trip through Colombia. He afterwards published an account of his travels which bears the following title: New Granada: twenty months in the Andes. New York, 1857. A copy has recently been added to the library of the New York Botanical Garden.

INDEX TO AMERICAN BOTANICAL LITERATURE
(1906)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in its broadest sense.

Reviews, and papers which relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions their kindness will be appreciated.

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Andrews, E. A. Polarity in the weeping willow. Torreya **6**: 1–5. 25 Ja 1906.

Arthur, J. C. New species of *Uredineae*—IV. Bull. Torrey Club **33**: 27–34. 8 F 1906.

New species in *Uromyces*, *Puccinia* (3), *Cronartium*, *Hyalopsora*, *Ceratelium* gen. nov., *Coleosporium*, *Uredo*, and *Aecidium* (4).

Bates, J. M. *Astragalus lotiflorus nebraskensis.* Torreya **5**: 215, 216. 10 Ja 1906.

Berry, E. W. Fossil plants along the Chesapeake and Delaware canal. Jour. N. Y. Bot. Gard. **7**: 5–7. Ja 1906.

Breazeale, J. F. Effect of certain solids upon the growth of seedlings in water cultures. Bot. Gaz. **41**: 54–63. *f. 1–4.* 26 Ja 1906.

Britton, N. L. The Cuban columneas. Torreya **5**: 215. 10 Ja 1906.

Cannon, W. A. A curious cactus fruit. Torreya **5**: 216, 217. 10 Ja 1906.

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Cockerell, T. D. A. The evolution of species through climatic conditions. Science II. **23**: 145, 146. 26 Ja 1906. [Illust.]

Cockerell, T. D. A. *Rhus* and its allies. Torreya **6**: 11, 12. 25 Ja 1906.

Criddle, N. The fly agaric (*Amanita muscaria*) and how it affects cattle. Ottawa Nat. **19**: 203, 204. 3 F 1906.

Evans, A. W. *Hepaticae* of Puerto Rico — VI. *Cheilolejeunea, Rectolejeunea, Cystolejeunea,* and *Pycnolejeunea.* Bull. Torrey Club **33**: 1–25. *pl. 1–3.* 8 F 1905.
Rectolejeunea and *Cystolejeunea* are new genera.

Farmar, L. *Oxalis adenophylla.* Curt. Bot. Mag. IV. **2**: *pl. 8054.* 1 Ja 1906.
Native of Chile.

Farmer, J. B. Sporogenesis in *Pallavicinia.* Bot. Gaz. **41**: 67–69. 26 Ja 1906.

Faull, J. H. A preliminary note on ascus and spore formation in the *Laboulbeniaceae.* Science II. **23**: 152, 153. 26 Ja 1906.

Gleason, H. A. Notes on some southern Illinois plants — III. Torreya **6**: 5–8. 25 Ja 1906.

Greene, E. L. *Madronella.* Leaflets **1**: 168, 169. 23 Ja 1906.
A new name for the genus commonly called *Monardella.*

Greene, E. L. New Asteraceous genera. Leaflets **1**: 173, 174. 23 Ja 1906.
Tumionella and *Hesperodoria* (without diagnoses).

Greene, E. L. A new northern *Antennaria.* Ottawa Nat. **19**: 197. 6 Ja 1906.
A. athabascensis sp. nov.

Greene, E. L. New species of *Isocoma.* Leaflets **1**: 169–173. 23 Ja 1906.
Descriptions of 11 new species.

Greene, E. L. New species of *Pentstemon.* Leaflets **1**: 161–167. 23 Ja 1906.
Descriptions of 21 new species.

Greene, E. L. Segregates from *Sieversia.* Leaflets **1**: 174–176. 23 Ja 1906; 177–179. 30 Ja 1906.
Acomastylis, with 5 species, and *Erythrocoma,* with 14 species, mostly new.

Greene, E. L. Various new species. Leaflets **1**: 180–182. 30 Ja 1906.
Petasites (2), *Euthamia,* and *Poygonatum* (3).

Harper, R. M. A statistical method for comparing the age of different floras. Torreya **5**: 207–210. 10 Ja 1906.

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Commelina nudiflora L.

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Murrill, W. A. Collecting fungi in Maine. Jour. N. Y. Bot. Gard. **6**: 199–202. [Ja 1906.]

Murrill, W. A. A key to the *Agariceae* of temperate North America. Torreya **5**: 213, 214. 10 Ja 1906.

Murrill, W. A. The *Polyporaceae* of North America — XIII. The described species of *Bjerkandera*, *Trametes*, and *Coriolus*. Bull. Torrey Club **32**: 633–656. 22 Ja 1906.

Nash, G. V. The *coco de mer* or double cocoanut. Jour. N. Y. Bot. Gard. **7**: 7–11. *f. 1.* Ja 1906.

Robinson, B. L. The generic concept in the classification of the flowering plants. Science II. **23**: 81–92. 19 Ja 1906.

Rydberg, P. A. *Astragalus* and its segregates as represented in Colorado. Bull. Torrey Club **32**: 657–668. 22 Ja 1906.
Seventeen genera (7 new) are recognized, with 84 species (3 new).

Rydberg, P. A. *Grayia* or *Eremosemium*. Torreya **6**: 8–10. 25 Ja 1906.

Schaffner, J. H. Additional observations on self-pruning. Ohio Nat. **6**: 450, 451. 15 Ja 1906.

Small, J. K. Studies in North American *Polygonaceae* — II. Bull. Torrey Club **33**: 51–57. 8 F 1906.

New species are described in *Eriogonum* (8) and *Polygonum*.

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